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November 24, 1998

Attorney Docket No.: 00786/071005

## Box Patent Application

Assistant Commissioner for Patents  
Washington, DC 20231

Presented for filing is a new divisional patent application of:

**Applicant:** GINO V. SEGRE, HENRY M. KRONENBERG, ABDUL-BADI ABOU-SAMRA, HARALD JUPPNER, JOHN T. POTTS, JR. AND ERNESTINA SCHIPANI  
**Title:** PARATHYROID HORMONE RECEPTOR AND DNA ENCODING SAME

The prior application is assigned of record to THE GENERAL HOSPITAL CORPORATION, a MASSACHUSETTS corporation, by virtue of an assignment submitted to the Patent and Trademark Office for recording on July 7, 1992 at 6189/0110.

Enclosed are the following papers, including those required to receive a filing date under 37 CFR §1.53(b):

	<u>Pages</u>
Specification	62
Claims	8
Abstract	1
Declaration	2
Drawing(s)	30

### Enclosures:

- Preliminary amendment, 2 pages.
- Postcard.

"EXPRESS MAIL" Mailing Label Number EL010098548US

Date of Deposit November 24, 1998

I hereby certify under 37 CFR 1.10 that this correspondence is being deposited with the United States Postal Service as "Express Mail Post Office To Addressee" with sufficient postage on the date indicated above and is addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231.

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November 24, 1998

Page 2

This application is a divisional (and claims the benefit of priority under 35 USC 120) of U.S. application serial no. 08/471,494, filed June 6, 1995. The disclosure of the prior application is considered part of (and is incorporated by reference in) the disclosure of this application.

Prior to calculating the fee, please enter the enclosed amendment cancelling certain claims.

Basic filing fee	760.00
Total claims in excess of 20 times \$18.00	0.00
Independent claims in excess of 3 times \$78.00	0.00
Fee for multiple dependent claims	0.00
Total filing fee:	\$ 760.00

A check for the filing fee is enclosed. Apply any other required fees or any credits to Deposit Account No. 06-1050, referencing the attorney docket number shown above.

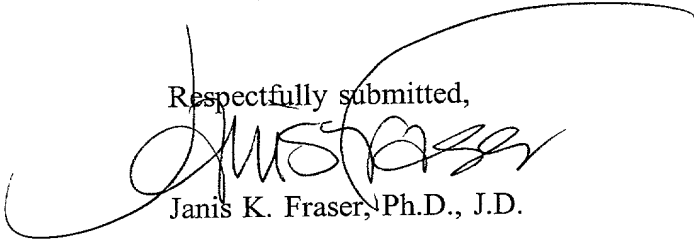
If this application is found to be incomplete, or if a telephone conference would otherwise be helpful, please call the undersigned at 617/542-5070.

Kindly acknowledge receipt of this application by returning the enclosed postcard.

Please send all correspondence to:

Janis K. Fraser, Ph.D., J.D.  
Fish & Richardson P.C.  
225 Franklin Street  
Boston, MA 02110-2804

Respectfully submitted,



Janis K. Fraser, Ph.D., J.D.

Reg. No. 34,819

Enclosures  
339760.B11

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant : Gino V. Segre et al. Art Unit:  
Serial No.: Examiner:  
Filed : HEREWITH  
Title : PARATHROID HORMONE RECEPTOR AND DNA ENCODING SAME  
Assistant Commissioner for Patents  
Washington, DC 20231

PRELIMINARY AMENDMENT

Prior to examination, please amend the application as follows:

In the Specification:

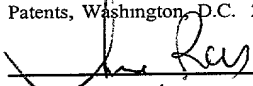
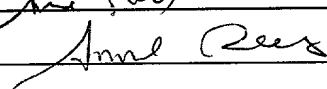
Insert the following on page 1, before the first paragraph: --This application is a divisional of U.S. Application Serial No. 08/471,494, filed June 6, 1995, and U.S. Application Serial No. 08/468,249, filed June 6, 1995, both of which are divisionals of U.S. Application Serial No. 07/864,475, now U.S. Patent No. 5,494,806, which was a continuation-in-part of U.S. Application Serial No. 07/681,702, filed April 5, 1991, and now abandoned.--

In the Claims:

Cancel claims 2-5, 9, 13-19, 22 and 26-38.

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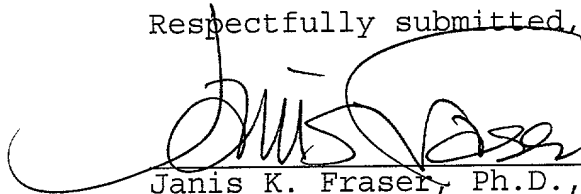
REMARKS

Upon entering of this amendment, claims 1, 6-8, 10-12, 20-21, 23-25 and 39 will be pending in this new divisional application, claims 2-5, 9, 13-19, 22 and 26-38 having been cancelled. No new matter has been added.

If there any additional charges or credits, please apply them to Deposit Account No. 06-1050.

Respectfully submitted,

Date: Nov. 24, 1998

  
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**APPLICATION  
FOR  
UNITED STATES LETTERS PATENT**

**TITLE:** PARATHROID HORMONE RECEPTOR AND DNA ENCODING  
SAME

**APPLICANT:** GINO V. SEGRE, HENRY M. KRONENBERG, ABDUL-BADI  
ABOU-SAMRA, HARALD JUPPNER, JOHN T. POTTS, JR.  
AND ERNESTINA SCHIPANI

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Anne Ray  
Anne Ray

**PARATHYROID HORMONE RECEPTOR AND DNA ENCODING SAME**

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Background of the Invention

Partial funding of the work described herein was provided by the U.S. Government, which has certain rights to the invention.

The invention relates to endocrine receptors.

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A crucial step in the expression of hormonal action is the interaction of hormones with receptors on the plasma membrane surface of target cells. The formation of hormone-receptor complexes allows the transduction of extracellular signals into the cell to elicit a variety of biological responses. For example, binding of a hormone such as follicle stimulating hormone (FSH), luteinizing hormone (LH), thyroid stimulating hormone (TSH), and chorionic gonadotropin (CG), to its cell surface receptor induces a conformational change in the receptor, resulting in the association of the receptor with a transductor molecule, the stimulatory guanine nucleotide (GTP) binding protein, a component of which is ( $G_s$ ). This association stimulates adenylate cyclase activity which in turn triggers other cellular processes such as protein phosphorylation, steroid synthesis and secretion, and the modulation of ion flux. Binding of other hormones, including arginine vasopressin (VP), angiotensin II, and norepinephrine, to their cell surface receptors results in the activation of other types of GTP binding proteins components such as ( $G_p$ ), which in turn stimulates the activity of the enzyme phospholipase C. The products of phospholipase C hydrolysis initiate a complex cascade of cellular events, including the

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mobilization of intracellular calcium and protein phosphorylation.

Parathyroid hormone (PTH) is a major regulator of calcium homeostasis, whose principal target cells occur in bone and kidney. Regulation of calcium concentration is necessary for the normal function of the gastrointestinal, skeletal, neurologic, neuromuscular, and cardiovascular systems. PTH synthesis and release are controlled principally by the serum calcium level: a low level stimulates and a high level suppresses both the hormone synthesis and release. PTH, in turn, maintains the serum calcium level by directly or indirectly promoting calcium entry into the blood at three sites of calcium exchange: gut, bone and kidney. PTH contributes to net gastrointestinal absorption of calcium by favoring the renal synthesis of the active form of vitamin D. PTH promotes calcium resorption from bone by inhibiting osteoblasts and, indirectly, by stimulating differentiation of the bone-resorbing cells, osteoclasts. It also mediates at least three main effects on the kidney: stimulation of tubular calcium reabsorption, enhancement of phosphate clearance, and promotion of an increase in the enzyme that completes synthesis of the active form of vitamin D. PTH exerts these effects primarily through receptor-mediated activation of adenylate cyclase, although receptor-mediated activation of phospholipase C by PTH has also been reported (Hruska et al., J. Clin. Invest. 79:230, 1987).

Disruption of calcium homeostasis may produce many clinical disorders (e.g., severe bone disease, anemia, renal impairment, ulcers, myopathy, and neuropathy) and usually results from conditions which produce an alteration in the level of parathyroid hormone. Hypercalcemia is a condition which is characterized by an elevation in the serum calcium

level. It is often associated with primary hyperparathyroidism in which an excess of PTH production occurs as a result of a lesion (e.g., adenoma, hyperplasia or carcinoma) of the parathyroid glands. Another type of hypercalcemia, humoral hypercalcemia of malignancy (HHM), is the most common paraneoplastic syndrome. It appears to result in most instances from the production by tumors (e.g., squamous, renal, ovarian or bladder carcinomas) of a novel class of protein hormone which shares amino acid homology with PTH. These PTH-related proteins (PTHrP) appear to mimic certain of the renal and skeletal actions of PTH and are believed to interact with the PTH receptor in these tissues. PTHrP is normally found at low levels in many tissues, including keratinocytes, brain, pituitary, parathyroid, adrenal cortex, medulla, fetal liver, osteoblast-like cells and lactating mammary tissues. In many HHM malignancies, PTHrP is found in the circulatory system at high levels, thereby producing the elevated calcium levels associated with HHM.

#### Summary of the Invention

The invention features isolated DNA comprising a DNA sequence encoding a cell receptor, preferably a parathyroid hormone receptor, of a vertebrate animal, which receptor has an amino acid sequence with at least 30% (preferably at least 50%, even more preferably at least 60%, and most preferably at least 75%) identity to the amino acid sequence shown in FIG. 3 (SEQ ID NO.: 3): i.e., when the closest match is made between the two amino acid sequences (using standard methods), at least 30% of the amino acid residues of the former sequence are identical to the amino acid residues of the latter sequence. By "isolated" is meant that the DNA is free of the coding sequences of those genes



that, in the naturally-occurring genome of the organism (if any) from which the DNA of the invention is derived, immediately flank the gene encoding the DNA of the invention. The isolated DNA may be single-stranded or double-stranded, and may be genomic DNA, cDNA, recombinant hybrid DNA, or synthetic DNA. It may be identical to a naturally-occurring, cell receptor- (e.g. PTH receptor) encoding DNA sequence, or may differ from such sequence by the deletion, addition, or substitution of one or more nucleotides. Single-stranded DNAs of the invention are generally at least 8 nucleotides long, (preferably at least 18 nucleotides long, and more preferably at least 30 nucleotides long) ranging up to full length of the gene or cDNA; they preferably are detectably labelled for use as hybridization probes, and may be antisense. Preferably, the isolated DNA hybridizes under conditions of high stringency to all or part of the DNA sequence show in FIG. 1 (SEQ ID NO.:1), FIG. 2 (SEQ ID NO.:2), FIG. 3 (SEQ ID NO.:3), or FIG. 6 (SEQ ID NO.:4). By "high stringency" is meant, for example, conditions such as those described herein below for the isolation of human kidney PTH receptor cDNA (also see Current Protocols in Molecular Biology, John Wiley & Sons, New York, 1989, hereby incorporated by reference). Most preferably, the animal is a mammal (such as an opossum, a rat, or a human), and the DNA sequence encodes substantially all of the amino acid sequence shown in FIG. 1 (SEQ ID NO.:1), FIG. 2 (SEQ ID NO.:2), FIG. 3 (SEQ ID NO.:3) or FIG. 6 (SEQ ID NO.:4); or is encoded by the coding sequence of one of the plasmids deposited with the American Type Culture Collection (ATCC) and designated ATCC Accession No. 68570 or 68571. The DNA of the invention may be incorporated into a vector [which may be provided as a purified preparation (e.g., a vector separated from the mixture of vectors which

make up a library)] containing a DNA sequence encoding a cell receptor of the invention (e.g. parathyroid hormone receptor) or fragment of the receptor, and a cell or essentially homogenous population of cells (e.g., prokaryotic cells, or eukaryotic cells such as mammalian cells) which contain the vector (or the isolated DNA described above). By "essentially homogenous" is meant that at least 99% of the cells contain the vector of the invention (or the isolated DNA, as the case may be). Preferably, this vector (e.g., R15B) is capable of directing expression of a parathyroid hormone receptor (for example, in a cell transfected or transformed with the vector).

In another aspect, the invention features a cell receptor, preferably parathyroid hormone receptor, (or an essentially purified preparation thereof) produced by expression of a recombinant DNA molecule encoding the cell receptor. An "essentially purified preparation" is one which is substantially free of the proteins and lipids with which it is naturally associated.

In a related aspect, the invention features a polypeptide which includes a fragment of a naturally-occurring cell receptor of the invention. Preferably, the polypeptide includes a fragment of a naturally-occurring parathyroid hormone receptor which is capable of binding parathyroid hormone or parathyroid hormone-related protein. In preferred embodiments, this fragment is at least six amino acids long, and has a sequence selected from the group including:

- (a) TNETREREVFDRLGMIYTVG; (SEQ ID NO.: 5)
- (b) YLYSGFTLDEAERLTEEEL; (SEQ ID NO.: 6)
- (c) VTFFLYFLATNYYWILVEG; (SEQ ID NO.: 7)
- (d) Y-RATLANTGCWDLSSGHKKWIIQVP; (SEQ. ID NO.: 8)
- (e) PYTEYSGTLWQIQMHYEM; (SEQ ID NO.: 9)

(f) DDVFTKEEQIFLLHRAQA; (SEQ ID NO.: 10)

(g) FFRLHCTRNY; (SEQ ID NO.: 11)

(h) EKKYLWGFTL; (SEQ ID NO.: 12)

(i) VLATKLRETNAGRCDTROQYRKLLK; or (SEQ ID NO. 13)

5 (j) a fragment (i.e., a portion at least six  
residues long, but less than all) or analog of (a) - (i)  
which is capable of binding parathyroid hormone or  
parathyroid hormone-related protein [wherein "analog"  
denotes a peptide having a sequence at least 50% (and  
10 preferably at least 70%) identical to the peptide of which  
it is an analog]. Preferably, the polypeptide of the  
invention is produced by expression of a recombinant DNA  
molecule or is synthetic (i.e., assembled by chemical rather  
than biological means). The invention provides a method for  
15 producing such a polypeptide, which method includes  
providing a cell containing isolated DNA encoding a cell  
receptor of the invention or receptor fragment and culturing  
this cell under conditions which permit expression of a  
polypeptide from the isolated DNA.

20 The invention also features an antibody (monoclonal  
or polyclonal), and a purified preparation of an antibody,  
which is capable of forming an immune complex with a cell  
receptor of the invention (preferably a parathyroid hormone  
receptor such as a human PTH receptor) such antibody being  
25 generated by using as antigen either (1) a polypeptide that  
includes a fragment of the cell receptor of the invention,  
or (2) a cell receptor of the invention which is on the  
surface of a cell. This antibody is preferably capable of  
neutralizing (i.e., partially or completely inhibiting) a  
30 biological activity of the cell receptor of the invention  
(i.e., a component of one of the cascades naturally  
triggered by the receptor when its ligand binds to it). In  
preferred embodiments, the antibody of the invention is

capable of forming an immune complex with parathyroid hormone receptor and is capable of neutralizing a biological activity of the PTH receptor (i.e. adenylate cyclase activation or phospholipase C stimulation)

Also within the invention is a therapeutic composition including, in a pharmaceutically-acceptable carrier, (a) a cell receptor of the invention, (b) a polypeptide containing a fragment of the cell receptor of the invention, or (c) an antibody to a cell receptor of the invention. These therapeutic compositions provide a means for treating various disorders characterized by overstimulation of the cell receptors of the invention by their ligand. In preferred embodiments, the polypeptides of the invention include the PTH receptor, fragments of the PTH receptor and antibodies which form immune complexes with the PTH receptor. These polypeptides and antibodies are useful as diagnostics, for distinguishing those cases of hypercalcemia related to PTH or PTHrP from those which are not.

The nucleic acid probes of the invention enable one of ordinary skill in the art of genetic engineering to identify and clone cell receptor homologs or cell receptors from any species which are related to the cell receptors of the invention, expanding the usefulness of the sequences of the invention.

Other features and advantages of the invention will be apparent from the following description of the preferred embodiments and from the claims.

#### Detailed Description

The drawings will first be briefly described.

DRAWINGS

FIG. 1 is a representation of the nucleic acid and amino acid sequence encoding the opossum kidney PTH/PTHrP receptor clone, OK-H. (SEQ ID NO.: 1)

5 FIG. 2 is a representation of the nucleic acid and amino acid sequence encoding the opossum kidney PTH/PTHrP receptor clone, OK-O. (SEQ ID NO.: 2)

10 FIG. 3 is a representation of the nucleic acid and amino acid sequence encoding the rat bone PTH/PTHrP receptor clone, R15B. (SEQ ID NO.: 3)

FIG. 4 is a comparison of the deduced amino acid sequences encoded by cDNAs from clones OK-O and R15B.

15 FIG. 5 is a comparison of the deduced amino acid sequences of OK-O, OK-H and R15B, lined up according to sequence homology.

FIG. 6 is a representation of the nucleic acid and amino acid sequence encoding the human PTH/PTHrP receptor. (SEQ ID NO.: 4)

20 FIG. 7 is a schematic representation of the rat bone PTH/PTHrP receptor cDNA, the human genomic DNA clone HPG1 and two cDNA clones encoding the human PTH/PTHrP receptor.

25 FIG. 8 is a hydrophobicity plot of the deduced amino acid sequence of the human kidney PTH/PTHrP receptor. Predicted membrane-spanning domains I through VII are indicated; A, B and C indicate additional hydrophobic regions.

FIG. 9 is a graph illustrating binding of PTHrP to COS cells transfected with OK-H.

30 FIG. 10 is a graph illustrating stimulation of intracellular free calcium by NlePTH in COS cells transfected with OK-H.

FIG. 11 is a graph illustrating binding of PTHrP to COS cells transfected with OK-O.

FIG. 12 is a graph illustrating stimulation of intracellular free calcium by NlePTH in COS cells transfected with OK-O.

FIG. 13 is a graph illustrating binding of PTHrP to COS cells transfected with R15B.

FIG. 14 is a graph illustrating stimulation of intracellular free calcium by NlePTH in COS cells transfected with R15B.

FIG. 15 is a graph illustrating stimulation of inositol phosphate metabolism by NlePTH in COS cells transfected with OK-H, OK-O, or R15B.

FIG. 16 is a graph illustrating cyclic AMP accumulation in COS cells transfected with CDM-8, OK-H, R15B by NlePTH.

FIG. 17 are graphs illustrating binding of  $^{125}\text{I}$ -labelled PTH(1-34) (A and B) and  $^{125}\text{I}$ -labelled PTHrP(1-36) (C and D) to COS-7 cells transiently expressing the human kidney (A and C) and the rat bone (B and D) PTH/PTHrP receptor; competing ligands included PTH(1-34) ( $\square$ ), PTHrP(1-36) (\*), PTH(3-34) ( $\blacksquare$ ), PTH(7-34) (+). Data are given as % specific binding and represent the mean  $\pm$  SD of at least three independent experiments.

FIG. 18 is a bar graph illustrating stimulated accumulation of intracellular cAMP in COS-7 cells transiently expressing the human kidney receptor. Data show the mean  $\pm$  SD, and are representative of at least three independent experiments.

FIG. 19 represents a Northern blot analysis of total RNA ( $\sim 10 \mu\text{g/lane}$ ) prepared from human kidney (A) and SaOS-2 cells (B). The blot was hybridized with the full length cDNA encoding the human kidney PTH/PTHrP receptor; positions of 28S and 18S ribosomal RNA bands are indicated.

FIG. 20 represents a Southern blot analysis of human genomic DNA digested with SstI, HindIII, and XhoI ( ~ 10µg/lane. The blot was hybridized with the full length cDNA encoding the human kidney PTH/PTHrP receptor.

FIG. 21 is a schematic diagram of the proposed arrangement, in a cellular membrane, of PTH/PTHrP rat bone receptor encoded by R15B.

#### MATERIALS AND METHODS

GENERAL: [Nle<sup>8,18</sup>, Tyr<sup>34</sup>]bPTH(1-34)amide (PTH(1-34)), [Nle<sup>8,18</sup>, Tyr<sup>34</sup>]bPTH(3-34)amide (PTH(3-34)), and [Nle<sup>8,18</sup>, Tyr<sup>34</sup>]bPTH(7-34)amide (PTH(7-34)) were obtained from Bachem Fine Chemicals, Torrance, CA; [Tyr<sup>36</sup>]PTHrP(1-36)amide (PTHrP(1-36)) was synthesized as described (Keutman et al., Endocrinology 117:1230, 1985) using an Applied Biosystems Synthesizer 420A. Dulbecco's modified Eagles medium (DMEM), EDTA/trypsin, and gentamycin were from GIBCO (Grand Island, NY); fetal bovine serum (FBS) was from Hyclone Laboratory, Logan, UT. Total RNA from human kidney was provided by Per Hellman, University Hospital, Uppsala, Sweden. Oligonucleotide primers were synthesized using an Applied Biosystems 380B DNA Synthesizer. Restriction enzymes, Klenow enzyme, T4 polynucleotide Kinase and T4 DNA ligase were from New England Biolabs, Beverly, MA. Calf alkaline phosphatase was from Boehringer Mannheim, Germany. All other reagents were of highest purity available.

#### CELLS

Cell lines used include COS cells, OK cells, SaOS-2 cells, CHO cells, AtT20 cells, LLC-PK1 cells, and UMR-106 cells, which are available from a variety of sources including the American Type Culture Collection (Rockland, Maryland), Accession Nos. CRL1650, CRL6551, HTB85, CCL61, CCL89, CL101, and CRL1161, respectively. ROS 17/2 and ROS

17/2.8 are available from a number of sources including Dr. Gideon Rodan (Merck Laboratories, West Point, PA). MC-3T3 cells are derived from mouse bone cells and are also available from a number of sources including Dr. Chohei Shigeno (Dept. of Biochem. Medicine, Hyoto Univ., Kyoto, Japan).

All cells were grown in a humidified 95% air, 5% CO<sub>2</sub> atmosphere and maintained in monolayer culture with Ham's F-12 or DMEM medium (Grand Island Biological Co.), supplemented with 5% or 10% fetal calf serum (M.A. Bioproducts, Walkersville, MD). The medium was changed every 3 or 4 days, and the cells were subcultured every 2 or 3 weeks by trypsinization using standard methods.

#### CLONING

Isolation of cDNA clones encoding the rat and opossum PTH/PTHrP receptors: Total RNA was initially isolated from rat osteosarcoma (ROS) cells (ROS 17/2.8) and opossum kidney (OK) cells, by standard methods using guanidium isothiocyanate (Ullrich et al., Science 196: 1313, 1977; Chirgwin et al. Biochemistry 24: 5294, 1979), and centrifugation through cesium chloride (Gilsen et al., Biochemistry 13: 2633, 1974). Poly A+ RNAs (mRNAs) were then recovered after passage of the total RNAs over oligo dT columns (Pharmacia, Piscataway, NJ) by the method of Aviv and Leder (Proc. Natl. Acad Sci. USA 69: 14087, 1972). The cDNA library from the ROS 17/2.8 mRNA was prepared from poly A+ RNA using the method of Gubler and Hoffman (Gene (Amst.) 25: 263, 1983). Oligo dT-primed and random-primed cDNAs were synthesized from poly A+ ROS 17/2.8 and OK cell mRNA, respectively (Aviv and Leder, supra). The cDNAs were ligated to BstX1 linkers (Invitrogen, San Diego, CA) and



size-selected by centrifugation (3 h, 55,000 xg) in a 5-20% potassium acetate gradient. The size-selected cDNA was then inserted into the plasmid vector, pCDNA I (Invitrogen), using the non-self annealing BstX1 restriction sites. The resultant plasmid libraries were then used to transform E. coli (MC1061/P3, Invitrogen) containing a larger helper plasmid, p3. The p3 plasmid possesses amber mutations in two genes which code for ampicillin and tetracycline resistance. Using ampicillin and tetracycline selection, only those cells containing both the p3 and a tRNA suppressor gene, which is contained within pCDNA I, were capable of growth. The transformed bacteria were then grown to confluence, and the plasmid DNAs isolated using standard techniques (e.g., see Ausubel et al., Current Protocols in Molecular Biology, John Wiley Sons, New York, 1989). These DNAs were then taken up in a DEAE-dextran solution, and used to transfect African Green Monkey kidney (COS) cells, which had been grown to 75% confluence in "sideflasks" (Nunc, Denmark).

Screening for COS cells containing plasmids capable of expressing functionally-intact ROS or OK cell parathyroid hormone/parathyroid hormone related-protein (PTH/PTHrP) receptor proteins was performed according to Gearing et al. (EMBO J. 8: 3676, 1989), with some minor modifications including DEAE-Dextran transfection in sideflasks. Forty-eight hours after transfection, the cells were tested for binding of <sup>125</sup>I-labeled [Tyr<sup>36</sup>]PTHrp (1-36) amide, using methods previously described (Yamamoto et al., Endocrinology 122: 1208, 1988), with the following exceptions: the time and temperature of the incubation were 2h and room temperature, respectively. After rinsing, the cells were fixed with 1.25% glutaraldehyde, and rinsed with 1% gelatin.

After snapping off the top of the sideflask, the remaining microscope slide was dipped into NTB-2 photographic emulsion (Eastman Kodak, Rochester, NY). After 3-4 days of exposure at 4°C, the slides were developed, fixed, and stained with 0.03% toluene blue. Screening of each slide was performed under a light microscope (Olympus). One pool of plasmid-DNA from ROS cells, and two pools of plasmid-DNA from OK cells, (10,000 independent clones), each gave rise to 3-4 transfected COS cells expressing the PTH/PTHrP receptor. These pools were subsequently subdivided. The subpools were used to transfect COS cells, and single clones were identified that expressed receptor protein capable of binding the radioligand.

Isolation of cDNA and genomic DNA clones encoding the human PTH/PTHrP receptor: A human kidney oligo dT-primed cDNA library ( $1.7 \times 10^6$  independent clones) in lambda GT10 and a genomic library of human placental DNA ( $2.5 \times 10^6$  independent clones) in EMBL3 (Sp6/T7) (Clontech, Palo Alto, CA) were screened by the plaque hybridization technique (Sambrook et al., Molecular Cloning: A Laboratory Manual, 2nd Ed. pp. 108-113, Cold Spring Harbor Laboratory, Cold Spring Harbor, NY, 1989) with the  $^{32}\text{P}$ -labelled (random primed labelling kit Boehringer Mannheim, Germany) BamHI/NotI 1.8kb restriction enzyme fragment encoding most of the coding sequence of the rat bone PTH/PTHrP receptor (Fig. 3). The nitrocellulose filters were incubated at 42°C for 4 hrs in a prehybridization solution containing 50% formamide, 4x saline sodium citrate (SSC;  $1 \times \text{SSC}$ : 300 mM NaCl, 30 mM NaCitrate, pH 7.0), 2x Denhardt's solution, 10% Dextran sulphate, 100  $\mu\text{g/ml}$  salmon sperm DNA (final concentration). The hybridizations were carried out in the same solution at 42°C for 18-24h. Filters were washed with

2x SSC/0.1% SDS for 30 minutes at room temperature and then with <sup>1</sup>x SSC/0.1% SDS for 30 minutes at 45°C. The films were exposed at -80°C for 18-24h using intensifying screens.

About 1,000,000 clones were screened from each library. Positive clones were plaque-purified and lambda phage DNA was isolated (Sambrook et al., *supra*). Cloned inserts were removed from phage DNA by digestion with restriction endonucleases HindIII and EcoRI (lambda GT10 library), or with XhoI and SstI (EMBL3 library), and were then subcloned into pCDNAI (Invitrogen, San Diego, CA) using the appropriate, dephosphorylated restriction sites. Sequencing of the CsCl<sub>2</sub>-purified subclones was performed according to Sanger et al. (Biochem 74:5463, 1977) by the dideoxy termination method (Sequenase version 2 sequencing kit, United States Biochemical Corporation, Cleveland, OH).

Reverse transcription and polymerase chain reaction

(PCR): 3 µg of poly (A)+ RNA from human kidney (Clontech, Palo Alto, CA) in 73.5 µl of H<sub>2</sub>O was incubated at 100°C for 30 seconds, quenched on ice, and then added to 20 µl of 5x RT buffer (1x RT buffer: 40 mM Tris-HCl, pH 8.2, 40 mM KCl, 6.6 mM MgCl<sub>2</sub>, 10 mM dithiothreitol, and dNTPs at 0.5 mM each), 2 µl (4 units) RNasin (Promega Biotec, Madison, WI), 1 µl (80 pmol/µl) of the human cDNA primer H12 (5'-AGATGAGGCTGTGCAGGT-3'; SEQ ID NO.: 14) and 80 units of avian myeloblastosis virus reverse transcriptase (Life Sciences, St. Petersburg, FL). The reaction mixture was incubated for 40 minutes at 42°C. One-tenth of the first strand synthesis reaction mixture was then amplified by PCR in a final volume of 100 µl containing 3 mM MgSO<sub>4</sub>, 200 µM dNTPs, 2 units of Vent polymerase (New England Biolab, Beverly, MA), and 2 µM each of the forward and the reverse primers (PCR conditions: denaturing for 1 min at 94°C,

annealing for 1 min at 50°C, and extension at 72°C for 3 minutes; 40 cycles).

Two independent PCRs were performed using two different forward primers: i) degenerate primer RK-1 (5'-GGAATTCCATGGGAGCGGCCCGGAT-3'; SEQ ID NO.: 15) based on the 5' coding end of the two previously cloned PTH/PTHrP receptors (described above), and ii) primer RK-2 (5'-CGGGATCCCGCGGCCCTAGGCGGT-3'; SEQ ID NO.: 16) based on the 5' untranslated region of the human genomic clone HPG1. Both PCR reactions used the reverse primer H26 (5'AGTATAGCGTCCTTGACGA-3'; SEQ ID NO.: 17) representing nucleotides 713 to 731 of the coding region of the human PTH/PTHrP receptor (Fig. 4). PCR products were blunt-ended using Klenow enzyme and cloned into dephosphorylated pcDNAI cut with EcoRV.

Northern blot analysis: Total RNA was extracted from SaOS-2 cells and from human kidney by the guanidine thiocyanate method (Chirgwin et al., Biochem. 18:5294, 1979). For Northern blot analysis, ~10 µg of total RNA was subjected to electrophoresis on a 1.5%/37% formaldehyde gel and blotted onto nitrocellulose filters (Schleicher and Schuell, Keene, NH). The hybridization conditions were the same as those for screening the phage libraries (see above). The filters were washed at a final stringency of 0.5x SSC/0.1% SDS for 30 min at 60°C and exposed for autoradiography.

Southern blot analysis: Human genomic DNA was prepared using the SDS/proteinase K method (Gross-Bellard et al., Eur. J. Biochem. 36:32, 1973). For Southern analysis, ~10 µg of DNA was digested with SstI, PvuII and XhoI; subjected to electrophoresis on a 0.8% agarose gel; and blotted onto nitrocellulose membranes (Schleicher and

Schuell, Keene, NH). The hybridization conditions were the same as those for screening the phage libraries (see above). The filters were washed at a final stringency of 0.5x SSC/0.1% SDS for 30 min at 55°C and exposed for autoradiography.

### FUNCTIONAL ASSAYS

Tests to characterize the functional properties of the cloned receptors expressed on COS cells included:

- I) binding of PTH and PTHrP fragments and analogues,
- II) stimulation of cyclic AMP accumulation by PTH and PTHrP fragments and analogues,
- III) increase of intracellular free calcium by PTH and PTHrP fragments and analogues, and
- IV) activation of inositol phosphate metabolism by PTH and PTHrP fragments and analogues. The methodologies are as follows:

#### Radioreceptor Assay

[Nle<sup>8</sup>,Nle<sup>18</sup>,Tyr<sup>34</sup>]bPTH-(1-34)amide (NlePTH), and [Tyr<sup>36</sup>]PTHrP(1-36)amide(PTHrP) were iodinated with Na<sup>125</sup>I (carrier free, New England Nuclear, Boston, MA) as previously reported (Segre et al., J. Biol. Chem. 254: 6980, 1979), and purified by reverse-phase HPLC. In brief, the labeled peptide was dissolved in 0.1% trifluoroacetic acid (TFA), applied to a C<sub>18</sub> Sep-pak cartridge (Waters Associates, Inc., Milford, MA) and eluted with a solution of 60% acetonitrile in 0.1% TFA. After lyophilization, the radioligand then was applied to C<sub>18</sub>-μBondapak column (3.9 mm x 30 cm. Waters Associates) and eluted over 30 min with a linear gradient of 30-50% acetonitrile-0.1% TFA at a flow rate of 2 ml/min. The radioligand eluted in two peaks; the first peak, which eluted at approximately 38% acetonitrile,

was used in these studies because it gave higher total and specific bindings. The specific activity was  $500 \pm 75$  mCi/mg, which corresponds to an average iodine-peptide ratio of 1.

5 COS-7 cells were grown in 15 cm plates in DMEM, 10% heat-inactivated FBS, 10 mg/L gentamycin until 80-90% confluent. Twenty-four hours after transfection by the DEAE/Dextran method (Sambrook et al., *supra*), with 1-2  $\mu$ g of plasmid DNA, the cells were trypsinized and replated in  
10 multiwell plastic dishes (16 or 35 mm diameter, Costar, Cambridge, MA) at a cell concentration of  $5 \times 10^4$  cells/cm<sup>2</sup>. Cell number increased only slightly after transfection. After continuing culture for another 48 h, radioreceptor assays were performed. The culture medium was  
15 replaced with buffer containing 50 mM Tris-HCL (pH 7.7), 100 mM NaCl, 2 mM CaCl<sub>2</sub>, 5 mM KCL, 0.5% heat-inactivated fetal bovine serum (GIBCO), and 5% heat-inactivated horse serum (KC Biological Inc., Lenexa, KS) immediately before studies were initiated. Unless otherwise indicated, studies  
20 were conducted with cells incubated in this buffer at 15°C for 4 h with  $4 \times 10^5$  cpm/ml ( $9.6 \times 10^{-11}$  M) of <sup>125</sup>I-labeled NlePTH or PTHrP.

Incubations were terminated by aspirating the buffer, and repeatedly (x3) washing the culture dishes  
25 containing the adherent cells with chilled 0.9% NaCl solution, over a 15 sec period. Cell-bound radioactivity was recovered by the sequential addition (x3) of 1 N NaOH (200  $\mu$ l) to each well. After 30 min at room temperature, the NaOH was transferred to a glass tube. A  
30 second and third extraction with 1 N NaOH (200  $\mu$ l) were combined with the first, and the total radioactivity was counted in a  $\gamma$ -spectrometer (Packard Instruments, Downers

Grove, IL). Tracer adherence to culture vessel without cells was negligible (<0.2% of total counts added), if vessels were preincubated with culture medium.

Determinations of cAMP accumulation

5           Intracellular cAMP accumulation was measured as described previously (Abou-Samra et al., J. Biol. Chem. 262:1129, 1986). Cells in 24-well plates were rinsed with culture medium containing 0.1% BSA and 2mM IBMX. The cells were then incubated with PTH or PTHrP for 15 min. at 37° C. 10 The supernatant was removed and the cells immediately frozen by placing the whole plate in dry ice powder. Intracellular cAMP was extracted by thawing the cells in 1ml of 50 mM HCl and analyzed by a specific radioimmunoassay using an anti-cAMP antibody (e.g., Sigma, St. Louis, MO). A cAMP analog (2'-O-monosuccinyl-adenosine 3':5'-cyclic monophosphate 15 tyrosyl methyl ester, obtained from Sigma) which was used as a tracer for cAMP was iodinated by the chloramine T method. Free iodine was removed by adsorbing the iodinated cAMP analog onto a C18 Sep-pak cartridge (Waters, Milford, MA). 20 After washing with dH<sub>2</sub>O, the iodinated cAMP analog was eluted from the Sep-pak Cartridge with 40% acetonitrille (ACN) and 0.1% trifluoroacetic acid (TFA). The iodinated cAMP analog was lyophilized, reconstituted in 1 ml 0.1% TFA, and injected into a C18 reverse phase HPLC column (Waters). 25 The column was equilibrated with 10% ACN in 0.1% TFA, and eluted with gradient of 10-30% ACN in 0.1% TFA. This allows separation of the mono-iodinated cAMP analog from the non-iodinated cAMP analog. The tracer is stable for up to 4 months when stored at -20° C. The standard used for the 30 assay, adenosine 3':5'-cyclic monophosphate, was purchased from Sigma. Samples (1-10 µl of HCl extracts) or standards (0.04-100 fmol/tube) were diluted in 50 mM Na-acetate

(pH 5.5), and acetylated with 10  $\mu$ l of mixture of triethylamine and acetic anhydride (2:1 vol:vol). After acetylation, cAMP antiserum (100  $\mu$ l) was added from a stock solution (1:4000) made in PBS (pH 7.4), 5 mM EDTA and 1% normal rabbit serum. The tracer was diluted in PBS (pH 7.4) with 0.1% BSA, and added (20,000 cpm/tube). The assay was incubated at 4° C overnight. The bound tracer was precipitated by adding 100  $\mu$ l of goat anti-rabbit antiserum (1:20 in PBS) and 1 ml of 7% polyethyleneglycol (MW 5000-6000), centrifuging at 2000 rpm for 30 min. at 4° C. The supernatant was removed and the bound radioactivity was counted in a  $\gamma$ -counter (Micromedic). Standard curves were calculated using the four-parameter RIA program supplied by Micromedic. Typically, the assay sensitivity is 0.1 fmol/tube, and the standard concentration that displaces 50% of tracer is 5 fmol/tube.

In an alternative method for assaying cAMP accumulation, COS cells transfected with PTH/PTHrP receptor cDNA are harvested with a plastic policeman into a solution containing 10 mM Tris-HCl (pH 7.5), 0.2 mM MgCl<sub>2</sub>, 0.5 mM ethyleneglycolbis( $\beta$ -amino ethyl ether) *N,N'*-tetra-acetic acid (EGTA) (Sigma) and 1 mM dithiothreitol (Sigma). Cells are homogenized by 20 strokes of tightly-fitting Dounce homogenizer, and centrifuged at 13,000 x g for 15 min at 4°C (Eppendorf, type 5412, Brinkmann Instruments, Inc., Westburg, NY). The pellet containing the plasma membranes is resuspended in the same buffer by several strokes with a Dounce homogenizer, and further diluted with the same buffer to a protein concentration of approximately 1.2 mg/ml, as determined by the method of Lowry et al. (Lowry et al., J. Biol. Chem 193: 265, 1951). Approximately 30  $\mu$ g (25  $\mu$ l) membrane are incubated with varying concentrations of



hormone or vehicle alone for 10 min at 37°C (final volume, 100 µl) in 50 mM Tris-HCl (pH 7.5), 0.8 mM ATP, 4 x 10<sup>6</sup> cpm [ $\alpha$ -<sup>32</sup>P] ATP (New England Nuclear, Boston, MA), 9 mM theophylline, 4.2 mM MgCl<sub>2</sub>, 26 mM KCl, 0.12% BSA, and an ATP-regenerating system containing 5 mM creatine phosphate (Schwartz/Mann Division, Becton-Dickenson & Co., Orangeburg, NY) and 0.1 mg/ml creatine phosphokinase (Shwartz/Mann). Incubations are initiated by addition of the membrane suspension and terminated by addition of 100 µl of a solution containing 20 mM cAMP, approximately 50,000 cpm [<sup>3</sup>H]cAMP, and 80 mM ATP. The reaction mixture is boiled, and the [<sup>32</sup>P]cAMP generated is purified by sequential chromatography on ion-exchange columns (Dowex 50 W-X4, Biorad Lab, Richmond, CA) and alumina (Sigma). The [<sup>32</sup>P]cAMP may be counted in a  $\beta$ -scintillation counter (Packard Instrument Co.), with correction for recovery of [<sup>3</sup>H]cAMP.

#### Determination of intracellular free calcium

Measurements of intracellular calcium levels in cells transfected with PTH/PTHrP receptor cDNAs were performed using Fura-2 AM (acetomethoxy ester of Fura-2, Molecular Probes Inc., Eugene, OR) loaded cells. Details of the methodology are:

Coverslips plated with COS cells were incubated in Fura-2 AM loading buffer containing, in mM: HEPES (N-[2-Hydroxyethyl]piperazine-N'-[2-ethanesulfonic acid]), 20; CaCl<sub>2</sub>, 1; KCl 5; NaCl, 145; MgSO<sub>4</sub>, 0.5; NaHCO<sub>3</sub>, 25; K<sub>2</sub>HPO<sub>4</sub>, 1.4; glucose, 10; and Fura-2 AM 91-(2-5'-carboxyoxazol-2'-yl)-6-aminobenzofuran-5oxy-(2'-amino-5'-methylphenoxy)ethane-N,N,N',N'-tetraacetic acid acetomethoxy ester), 0.5; at 37°C at pH7.4, aerated with 95% air and 5% CO<sub>2</sub> for 45 minutes. Cells loaded with Fura-2 AM

were then washed with a modified Krebs-Heinseleit (KH) buffer containing, in mM: HEPES, 20;  $\text{CaCl}_2$ , 1; KCl, 5; NaCl, 145;  $\text{MgSO}_4$ , 0.5;  $\text{Na}_2\text{HPO}_4$ , 1; glucose, 5; pH7.4. To check that cleavage of the ester occurred, the excitation spectra after different times of Fura-2 AM incubation were measured. At 5 min. after the start of incubation, the excitation spectrum peaked at approximately 360 nm, reflecting incomplete hydrolysis of Fura-2 AM, whereas beyond 30 min. the excitation spectrum peaked at 345 nm, characteristic of Fura-2.

To measure fluorescence of individual cells, the cover slips were placed in a microscope tissue chamber (Biophysica Technologies, Inc., MD). The chamber consisted of a shallow, sloped compartment made of Teflon with a silicone rubber seal. The cover slips served as the bottom of the chamber. A heater/cooler ring was encased in the silicone rubber which sealed the coverslip in place. Temperatures were varied between 22°C and 37°C by applying 0-7.4 V to the heater. If the temperature is not specifically stated, the experiment was performed at 37°C. The chamber was mounted on the stage of an inverted microscope (Zeiss IM-35, Thornwood, NY). Fura-2 fluorescence was excited with a 75 watt Xenon arc lamp placed at the focal point of a condenser (Photon Technologies International (PTI) Inc., NJ). Grating monochromators, alternated by a rotating chopper in which mirror vanes alternate with transmitting sectors, were used for selecting wavelengths. The monochromator outputs were combined to form a common optical path which exited the source housing through an adjustable iris. The light then passed through quartz lenses and a dichroic mirror through a 100x Nikon Fluor objective. A photon-counting PMT device

detection was used to measure the light output. Data analysis was performed using PTI software run on an IBM-compatible AT/286 computer using the MS-DOS operating system. Data was retained and manipulated in a packed binary format.

Intracellular calcium concentrations were calculated according to the formula:  $[Ca^{2+}]_i = K_d(R - R_{min}) / (R_{max} - R)B$ , where R is the ratio of fluorescence of the cell at 340 and 380 nm; R<sub>max</sub> and R<sub>min</sub> represent the ratios of Fura-2 fluorescence intensity at 340 and 380 nm excitation wavelengths in the presence of a saturating amount of calcium and effectively zero calcium, respectively; B is the ratio of fluorescence of Fura-2 at 380 nm in zero calcium to that in saturating amounts of calcium; and K<sub>d</sub> is the dissociation constant of Fura-2 for calcium. To determine R<sub>max</sub>, at the end of an experiment ionomycin was added to the Fura-2 AM loaded cells to equilibrate Ca<sup>2+</sup> between the extracellular (1mM) and intracellular environments. To calculate R<sub>min</sub>, 1mM EGTA was then added to the bathing solution. Different dissociation constants were used at the different temperatures: 224 nM at 34-37°C and 135 nM at 24-27°C.

#### Determination of inositol phosphate

The level of inositol phosphate metabolism was determined in COS cells transfected with PTH/PTHrP receptors using previously published methods (Bonventre, et al., J. Biol. Chem. 265: 4934, 1990).

### RESULTS

#### Molecular characterization

Two independent clones (OK-H and OK-O), both of which were isolated from the OK cell cDNA library, had

lengths of approximately 2 kilobases. The determined nucleotide sequence and predicted amino acid sequence of these clones are shown in Figs. 1 (SEQ ID NO.:1) and 2 (SEQ ID NO.:2) respectively. The R15B clone isolated from the ROS cell cDNA library had a length of approximately 4 kilobases. The determined nucleotide sequence and predicted amino acid sequence of the rat bone PTH/PTHrP receptor is depicted in Fig. 3 (SEQ ID NO.:3).

The three cDNA clones appear to be full-length by the criteria of having codons encoding methionine residues that are predicted to be the likely candidates as initiator methionines. These methionine codons are followed by amino acid sequences (deduced from the DNA) with properties suggesting that they are "signal-peptide" sequences. All three receptor cDNAs have stop codons at locations that permit these receptors to "fit" a putative seven-membrane spanning model, a model typical for G-protein-linked receptors. Most importantly, all three cloned receptors bind ligands and, when activated, are capable of activating intracellular effectors. These properties suggest that all three of the isolated clones encode full-length cDNAs.

Fig. 4 demonstrates the high degree of homology between the amino acid sequences encoded by the cDNAs from OK-O and ROS 15B. There is an overall 87% homology and a 77.8% amino acid identity between these two receptors. This high level of identity over long stretches of amino acids demonstrates that the amino acid sequence of the PTH receptor is evolutionarily conserved to a high degree. This allows the data from both OK-O and R15B to be extrapolated to other species, including human.

Fig. 5 shows the deduced amino acid sequences of all three cloned cDNAs lined up according to sequence homology. The OK-H sequence is identical to OK-O except in the C-

terminus tail, where the OK-O sequence totals 585 amino acids whereas the OK-H sequence stops at 515 amino acids. This difference is attributable to a single nucleotide (G) deleted in the OK-H sequence compared to the OK-O sequence, causing a frame shift and early stop codon in the former. It is not known whether OK-O and OK-H represent the products of two separate genes or of a laboratory artifact.

Some G-protein-coupled receptors are encoded by intronless genes (Kobilka et al., Nature 329:75, 1987); Kobilka et al., J. Biol. Chem. 262:7321, 1987; Heckert et al., Mol. Endocrinol. 6:70, 1992; Kobilka et al., Science 238:650, 1987; Bonner et al., Science 237:527, 1987; Sunahara et al., Nature 347:80, 1990). To isolate a human PTH/PTHrP receptor cDNA, both a human cDNA library and a human genomic library were screened with a probe (BamHI/NotI) representing most of the coding region of the rat bone PTH/PTHrP receptor (Fig. 3). Screening the human kidney cDNA library led to the isolation of the clone HK-1 (Fig. 6) [SEQ ID NO.: 6]. Since one of the two EcoRI cloning sites of lambda GT10 proved to be eliminated as a result of the library construction, the HindIII/EcoRI phage fragment containing the cDNA insert and ~250 bp of the 37 kb (left) lambda arm was subcloned into the corresponding restriction sites in pcDNAI. DNA sequencing revealed that the cloned cDNA contained ~1000 bp of the 3' coding region and ~200 bp of the 3' non-coding region including an A-rich 3' end. The coding region 5' to the XhoI site was subsequently used to re-screen the library and led to the isolation of the clone HK-2 which, after subcloning into pcDNAI, proved to contain ~1400 bp of the coding region. For the third screening of the library, the PvuII/PstI fragment of HK-2 was used; the isolated clone HK-3 proved to be identical to HK-2.

The genomic library screening ( $\sim 10^6$  pfu) resulted in the isolation of four independent clones. Comparison of Southern blot analyses of restriction enzyme digests of these clones with that of normal genomic DNA, revealed that one 15 kb genomic clone, HPG1 (also referred to as HG4A), contained a SstI/SstI fragment that had the same size as one hybridizing DNA species from normal human genomic DNA digested with SstI (see below). The hybridizing 2.3 kb SstI/SstI DNA fragment and an  $\sim 8$  kb XhoI fragment which comprised the SstI/SstI fragment were both subcloned into pCDNAI. Further Southern blot analysis of the SstI/SstI DNA fragment revealed that an  $\sim 1000$  bp BamHI/SstI fragment encoded a portion of the human PTH/PTHrP receptor which later proved to represent the exon encoding the putative signal peptide and the 5' non-translated region which is interrupted by an  $\sim 1000$  bp intron (Fig. 7).

To isolate the remaining  $\sim 450$  nucleotides of the coding region, poly (A)+ RNA from human kidney was reverse transcribed after priming with H12 (Fig. 7). After single strand synthesis, two independent PCRs were performed using two different forward primers: i) a degenerate primer RK-1 based on the 5' coding end of the two previously cloned PTH/PTHrP receptors, OK-O and R15B; and ii) primer RK-2 based on the 5' non-coding region of HPG1. H-26 was used as the reverse primer for both reactions. Southern blot and restriction map analyses confirmed the expected size of the amplified DNA encoding the human PTH/PTHrP receptor. The blunt-ended PCR products encoding the 5' end of the human PTH/PTHrP were cloned into pCDNAI using the dephosphorylated EcoRV sites. Sequence analysis of each PCR clone confirmed their 5' nucleotide difference due to the difference in forward primer sequence, but revealed otherwise identical

sequences. Nucleotide sequencing of both strands of the human PTH/PTHrP receptor cDNA revealed an open reading frame encoding a 593-amino acid protein (Fig. 6, SEQ ID NO.:4).

5 The full-length human kidney PTH/PTHrP receptor cDNA, HKrk, was constructed using the BamHI/PvuII fragment of PCR clone #2 and HK-2. Using the full-length cDNA encoding the human PTH/PTHrP receptor, Northern blot analysis of total RNA (~10 µg/lane) from human kidney and SaOS-2 cells revealed one major hybridizing DNA species of 10 ~2.5 kb (Fig. 19). The XhoI digest of normal human genomic DNA, when probed with the same full-length cDNA (Fig. 20), revealed one major hybridizing species of about 5.5 kb, and two DNA species of 4 and 8 kb which weakly hybridized. These data suggest that the human PTH/PTHrP receptor is the product of a single gene. This full-length clone was then transiently expressed in COS-7 cells for functional and biological characterization by the methods cited above.

15 Comparison of the human receptor with the opossum kidney PTH/PTHrP receptor and the rat bone PTH/PTHrP receptor, revealed 81% and 91% amino acid sequence identity, respectively, and consequently a very similar hydrophobicity plot (Fig. 8). All extracellular cysteines including the two cysteine residues in the presumed signal peptide are conserved, as are all potential, extracellular 20 N-glycosylation sites. A number of the amino acids which were not identical between the human kidney and rat bone PTH/PTHrP receptors were found to be conserved between the human and the opossum receptors. These conserved amino acids include an Arg to Leu at 51, an Arg to Trp at 58, an Arg to His at 262, an Asp to His at 358, an Ile to Thr at 422, and a Thr to Leu at 427.

#### Biological Characterization

Functional characterization of the biological properties of the opossum and rat PTH/PTHrP receptors was performed in transiently transfected COS cells by a radioreceptor assay technique using both  $^{125}\text{I}$ -PTHrP and  $^{125}\text{I}$ -NlePTH as radioligands, and by bioassays that measure ligand-stimulated cAMP accumulation, increase in intracellular free calcium, and stimulation of inositol phosphate metabolism, by the methods cited above.

Fig. 9 demonstrates that COS cells expressing OK-H bind  $^{125}\text{I}$ -PTHrP. These data also demonstrate that binding of PTHrP is inhibited when intact PTH (1-34) or PTH analogues which are shortened at their amino terminus (i.e. the 3-34 and 7-34 analogues, which contain Nle substitutions for methionine at positions 8 and 18 and a tyrosine substitution for phenylalanine at position 34) are used as competitors for binding. Similarly, binding of  $^{125}\text{I}$ -NlePTH to COS cells expressing OK-H was inhibited when PTHrP or PTHrP fragments were used as competitors. These data indicate that PTH and PTHrP both bind to the receptor encoded by OK-H.

Fig. 10 demonstrates that COS cells expressing OK-H increase their concentration of intracellular free calcium when exposed to NlePTH, but to a smaller extent (mean = 39 nm), or not at all, when compared to COS cells expressing OK-O or R15B receptors (Fig. 12 and Fig. 14) and stimulated with NlePTH. Unlike COS cells expressing OK-O or R15B, COS cells expressing OK-H do not show a detectable increase in metabolism of inositol phosphate when stimulated with NlePTH (Fig. 15).

Fig. 11 demonstrates that COS cells expressing OK-O bind  $^{125}\text{I}$ -PTHrP. These data also demonstrate that binding of PTHrP is inhibited when intact PTH (1-34) or PTH analogues which are shortened at their amino terminus (i.e.



the 3-34 and 7-34 analogues, which contain Nle substitutions for methionine at positions 8 and 18 and a tyrosine substitution for phenylalanine at position 34) are used as competitors for binding. Similarly, binding of  $^{125}\text{I}$ -NlePTH to COS cells expressing OK-H was inhibited when PTHrP or PTHrP fragments were used as competitors. These data indicate that PTH and PTHrP both bind to the receptor encoded by OK-0.

Fig. 12 demonstrates that COS cells expressing OK-0 increase their concentration of intracellular free calcium and their rate of inositol phosphate metabolism after stimulation with NlePTH and PTHrP (Fig. 15).

Fig. 13 demonstrates that COS cells expressing R15B bind  $^{125}\text{I}$ -PTHrP. These data also demonstrate that binding of PTHrP is inhibited when intact PTH (1-34) or PTH analogues which are shortened at their amino terminus (i.e. the 3-34 and 7-34 analogues, which contain Nle substitutions for methionine at positions 8 and 18 and a tyrosine substitution for phenylalanine at position 34) are used as competitors for binding. Similarly, binding of  $^{125}\text{I}$ -NlePTH to COS cells expressing OK-H was inhibited when PTHrP or PTHrP fragments were used as competitors. These data indicate that PTH and PTHrP both bind to the receptor encoded by R15B.

Fig. 14 demonstrates that COS cells expressing R15B increase their concentration of intracellular calcium to an extent similar to stimulated COS cells expressing OK-0.

Fig. 15 demonstrates that COS cells expressing R15B or OK-0 increase their rate of phosphatidyl inositol hydrolysis, as evidenced by the rapid increase in inositol trisphosphate ( $\text{IP}_3$ ) and inositol bisphosphate ( $\text{IP}_2$ ) accumulation after stimulation of the cells with NlePTH or PTHrP. Conversely, COS cells expressing OK-H did not show

any detectable increase in inositol trisphosphate and inositol bisphosphate accumulation after stimulation with NlePTH or PTHrP. These data suggest that the PTH receptor encoded by R15B and OK-O is coupled to phospholipase C, presumably through  $G_p$ . Since the only difference between OK-O and OK-H is in the cytoplasmic C-terminal tail, these data strongly suggest that the C-terminus of the PTH receptor encoded by OK-O and R15B is involved in the activation of phospholipase C.

Fig. 16 demonstrates that COS cells expressing R15B and OK-H increase cAMP accumulation after stimulation with NlePTH. Similar results were obtained in COS cells expressing OK-O. No cAMP stimulation was detected in COS cells transfected with the cDM8 vector alone. These data suggest that PTH receptor coupling to adenylate cyclase does not require the full length C-terminal cytoplasmic tail of the receptor.

These data demonstrate that all three PTH/PTHrP receptors cloned from both OK and ROS cell cDNA libraries bind the amino-terminal ligands of both peptides equivalently. Activation of all these receptors by ligand stimulates adenylate cyclase (as measured by increased intracellular cAMP), presumably through activation of one class of guanine nucleotide binding proteins (G-proteins). G-proteins have a trimeric peptide structure in which one of the subunits, alpha, is distinct, and the other two, beta and gamma, are identical or highly homologous. One of these G-proteins ( $G_s$ ) contains G-alpha-"stimulatory" (G-alpha-s) which is involved in the activation of adenylate cyclase.

Binding of ligand to OK-O and R15B, but not to OK-H, also increases intracellular free calcium and stimulates metabolism of inositol phosphate. These properties strongly

suggest that activation of both OK-O and R15B receptors by ligand results in stimulation of a second intracellular effector, phospholipase C. The coupling mechanism between these activated receptors and phospholipase C is likely to be a G-protein which is distinct from G<sub>s</sub>. In contrast, the properties of the activated OK-H receptor which is truncated at the carboxy terminus, suggest that it may not activate phospholipase C, or that it activates phospholipase C inefficiently.

The biochemical role of the carboxy-terminal tail of the PTH/PTHrP receptor was further investigated by the construction of a carboxy-terminally-truncated rat receptor, R480, by standard PCR technology using R15B as a template and an upstream primer containing a stop codon inserted at position 481. Briefly, the upstream primer was a synthetic oligonucleotide based on nucleotides 1494-1513 of the rat cDNA sequence (see Fig. 3; SEQ ID NO.: 3) to which a stop codon and an XbaI cloning site were added. Thirty PCR cycles were carried out, each cycle consisting of 1 min at 92°C for denaturation, 1 min at 60°C for annealing, and 1 min at 72°C for extension. The product was cut with NsiI and XbaI and purified by gel electrophoresis. R15B was sequentially digested with XbaI and NsiI, and the purified PCR product was then ligated into the XbaI-NsiI cut R15B vector. The resulting plasmid, R480, was amplified in bacteria and sequenced.

R480 encodes 480 amino acids that are identical to those in the 591 amino acids receptor. This truncated cDNA was expressed in COS-7 cells (transient expression) and in CHO cells (stable expression). Both COS-7 and CHO cells expressing the truncated receptor, R480, and the wild type receptor, RB, bind PTH(1-34) with equivalent affinities.

When activated, R480 stimulates cAMP accumulation in COS7 and CHO cells as efficiently as does the wild type receptor. In contrast to the wild type receptor, R480 did not mediate any increase in  $[Ca^{2+}]_i$  when stimulated by PTH in either the COS-7 cells or the CHO cells. These data indicate that the molecular requirements for activation of phospholipase C and adenylyate cyclase by PTH/PTHrP receptor are distinct from each other, and point to a major role of the carboxy-terminal tail of the PTH/PTHrP receptor in coupling to phospholipase C but not to adenylyate cyclase. Of course, it is also possible that activated PTH/PTHrP receptors may activate additional G-proteins and/or intracellular effector molecules.

Analysis of COS-7 cells transfected with the cloned human PTH/PTHrP receptor demonstrated that radiolabelled PTH(1-34) and PTHrP(1-36) (~200,000 cpm) bound to the expressed receptors with similar efficiency (specific binding:  $10.1 \pm 3.7\%$  and  $7.6 \pm 6.0\%$ , respectively) to that observed for COS-7 cells expressing R15B (specific binding:  $8.1 \pm 3.5\%$  and  $7.1 \pm 4.1\%$ , respectively). The expressed human PTH/PTHrP receptors bound PTH(1-34) with 2-fold higher apparent  $K_d$  than did the rat bone PTH/PTHrP receptor: ~5 nM versus ~10 nM (Fig. 17). However, despite their high degree of amino acid homology, the two receptors showed significant differences in affinity for PTH(3-34) and PTH(7-34). PTHrP(1-36) displayed a 2- to 4-fold lower affinity for the human PTH/PTHrP receptor than for the rat receptor (~35 nM for HKrk versus ~10 nM for R15B) which appeared more pronounced when PTHrP(1-36) was used as radioligand. The affinities for PTH(3-34) and PTH(7-34) were 7- and 35-fold higher with the expressed HKrk than with R15B (~7 nM versus ~45 nM for PTH(3-34), respectively; ~60 nM versus ~2000 nM

for PTH(7-34), respectively). In COS-7 cells expressing either receptor, both PTH(1-34) and PTHrP(1-36) stimulated the increase in intracellular free calcium and cAMP accumulation to the same extent (Fig. 18).

#### 5 Relationship of PTH/PTHrP receptors

10 The amino acid sequence of the human PTH/PTHrP receptor displays a very high degree of conservation compared to the bone PTH/PTHrP receptor from rat, a eutherian mammal, while its sequence identity with the PTH/PTHrP receptor with the opossum, a marsupial mammal, is less marked. Like the opossum kidney and the rat bone receptor, the human kidney receptor induces an increase in both intra-cellular cAMP and intracellular free calcium when challenged with either PTH or PTHrP. Despite the high  
15 degree of homology between the human PTH/PTHrP receptor and the opossum and rat homologs, the transiently expressed human receptor has some functional characteristics that are distinct from those of the rat bone receptor. These include a slightly higher affinity for PTH(1-34) and a significantly decreased affinity for PTHrP(1-36). Higher affinities were  
20 observed for PTH(3-34) and in particular for PTH(7-34), the affinity of which for the human receptor was about 35-fold higher in comparison to the rat bone receptor. These findings may have significant implications for the future  
25 development of PTH/PTHrP analogues, since they predict that species-specific tissues would be the appropriate tissues for testing the potency of antagonists (and agonists) *in vitro*.

#### 30 Relationship of PTH/PTHrP receptors to other receptors

The biochemical properties of PTH and PTHrP receptors suggest that they are members of the class of membrane receptor molecules known as G-protein-linked membrane receptors. The structural features of well-

characterized G-protein receptors indicate that they all have at least seven regions of several consecutive hydrophobic amino acids, each of which regions is of sufficient length to span the plasma membrane.

5 One subfamily of G-protein-linked membrane receptors, termed the glycopeptide receptor subfamily, includes receptors that bind and are activated by glycopeptide hormones (thyroid-stimulating hormone, luteinizing hormone, follicle-stimulating hormone, and  
10 chorionic gonadotropin). All of these receptors are characterized by (1) extensive putative amino-terminal extracellular domains (greater than 300 amino acids) that are thought to contain some or all of the ligand-binding domains, and (2) considerable amino-acid homology, particularly in the seven putative transmembrane domains. A  
15 second subfamily, termed the adrenergic/muscarinic subfamily, includes receptors that are activated by small ligands, such as the catecholoamines, neuromuscular transmitters, and retinol. These receptors are all  
20 characterized by relatively short (25-75 amino acids) putative amino-terminal extracellular domains, as well as considerable amino acid homology, particularly in the seven putative transmembrane domains. Activation of these receptors by their ligands appears to involve at least  
25 several of the multiple transmembrane domains, and does not appear to involve the amino-terminal portion of the receptors.

Several structural characteristics which can be deduced from the predicted amino acid sequence of the rat  
30 PTH/PTHrP receptor (Fig. 3) indicate that the PTH/PTHrP is a G-protein-linked receptor. The amino terminus shows characteristic features of a signal peptide, including a hydrophobic domain and the presence of three consecutive

leucine residues. This amino acid stretch of 20-28 amino acids may serve as a leader sequence, similar to the amino terminus preceding the extracellular domains of other glycoprotein receptors. There is also a cluster of seven hydrophobic segments which represent putative membrane-spanning domains (Fig. 19).

The predicted amino acid sequences of the opossum kidney, rat bone and human kidney PTH/PTHrP receptors indicate that they do not fit comfortably into either of these G-protein linked receptor subfamilies. Overall homology of the rat and human PTH/PTHrP receptors with the glycopeptide receptor and adrenergic/muscarinic subfamilies is approximately 10 to 20%, with a somewhat higher degree of homology within the transmembrane domains. The latter is to be expected because of the limited menu of hydrophobic amino acids that could occur in those regions. Twenty percent homology is far less than that found among the receptors generally accepted to be members of each of these subfamilies. Additionally, there are no portions of these sequences that have what could be characterized as intense homology (i.e., exactly matching amino acid sequences), even over limited regions.

Recent comparison with the newly characterized secretin and calcitonin receptors (Ishihara et al., EMBO J 10:1635, 1991; Lin et al., Science 254:1022, 1991) has revealed between 30 and 40% identity between these receptors and the PTH/PTHrP receptor. Although the PTH/PTHrP receptor is more than 100 amino acids longer than the calcitonin receptor, there is an ~32% identity between the amino acid sequences of the opossum kidney PTH/PTHrP receptor (SEQ ID NO NO.:2) and porcine kidney calcitonin receptor (GenBank accession no. M74420). A stretch of 17 out of 18 amino acids in the putative transmembrane domain VII are

identical. Also, two out of four N-linked glycosylation sites and the position of seven out of eight potentially extracellular cysteines are conserved. Major differences between the two receptors appear to lie in their NH<sub>2</sub>-terminal and COOH-terminal domains. Comparison of amino acid sequences of the rat secretin receptor (GenBank accession no. X59132) and the human PTH/PTHrP receptor indicates that there is a 43% identity between these two receptors, with a stretch of 21 out of 25 amino acids of the putative transmembrane domain VII being identical. The similarity between the PTH/PTHrP, calcitonin and secretin receptors suggests that they represent a new family of seven transmembrane-spanning G protein-coupled receptors that activate adenylate cyclase. Given the amino acid sequences of these receptors, those skilled in art would be able to compare these sequences for regions of identity which would be useful in the design of nucleic acid probes which could then be used for the identification and isolation of other receptors which would belong to this family.

#### Deposit of Clones

Under the terms of the Budapest Treaty on the International Recognition of the Deposit of Microorganisms for the Purpose of Patent Procedure, the cDNA expression plasmids R15B, OK-O, and OK-H; the phage HPG1; and a plasmid (termed 8A6) containing part of the human clone have been deposited with the American Type Culture Collection (ATCC), where they bear the respective accession numbers ATCC No. 68571, 68572, 68573, 40998 and 68570. Applicants' assignee, The General Hospital Corporation, represents that the ATCC is a depository affording permanence of the deposits and ready accessibility thereto by the public if a patent is



granted. All restrictions on the availability to the public of the material so deposited will be irrevocably removed upon the granting of a patent. The material will be available during the pendency of the patent application to one determined by the Commissioner to be entitled thereto under 37 CFR 1.14 and 35 U.S.C. 122. The deposited material will be maintained with all the care necessary to keep it viable and uncontaminated for a period of at least five years after the most recent request for the furnishing of a sample of the deposited plasmid, and in any case, for a period of at least thirty (30) years after the date of deposit or for the enforceable life of the patent, whichever period is longer. Applicants' assignee acknowledges its responsibility to replace the deposits should the depository be unable to furnish a sample when requested due to the condition of the deposit.

POLYPEPTIDES

Polypeptides according to the invention include the opossum and rat and human parathyroid hormone receptors as shown in Figs. 1-3 and 6, respectively, and any other naturally-occurring receptor which can be produced by methods analogous to those used to clone and express these receptors, or by methods utilizing as a probe all or part of one of the sequences described herein. In addition, any analog or fragment of a PTH receptor capable of binding to a parathyroid hormone or a parathyroid hormone-related protein is within the invention.

Specific receptor analogs of interest include full-length or partial receptor proteins having an amino acid sequence which differs only by conservative amino acid substitutions: for example, substitution of one amino acid for another of the same class (e.g., valine for glycine; arginine for lysine, etc.), or by one or more non-

conservative amino-acid substitutions, deletions, or insertions located at positions which do not destroy the receptor's ability to bind to parathyroid hormone or parathyroid hormone-related protein.

5           Specific receptor fragments of particular interest include, but are not limited to, portions of the receptor deduced to be extracellular from the primary amino acid sequence, using a hydrophobicity/hydrophilicity calculation such as the Chou-Fasman method (see, e.g., Chou and Fasman, 10   Ann. Rev. Biochem. 47:251, 1978). Hydrophilic domains, particularly ones surrounded by hydrophobic stretches (e.g., transmembrane domains) of at least 10 amino acids, present themselves as strong candidates for extracellular domains. Fig. 21 illustrates a predicted arrangement of 15   extracellular, intracellular, and transmembrane domains of one PTH receptor.

          Examples of specific PTH receptor fragments include those with the following amino acid sequences (shown as standard single-letter symbols), derived from the deduced 20   amino acid sequence of the R15B clone:

Extracellular domains:

RP-1:  TNETREREVFDRLGMIYTVG (SEQ ID NO.: 5)  
RP-2:  VLYSGFTLDEAERLTEEEL (SEQ ID NO.: 6)  
RP-3:  VTFFLYFLATNYYWILVEG (SEQ ID NO.: 7)  
25   RP-4:  Y-RATLANTGCWDLSSGHKKWIIQVP (SEQ ID NO.: 8)  
RP-5:  PYTEVSGTLWQIQMHYEM (SEQ ID NO.: 9)  
RP-6:  DDVFTKEEQIFLLHRAQA (SEQ ID NO.: 10)

Intracellular domains:

30   RPI-7:  FRRLHCTRNY (SEQ ID NO.: 11)  
RPI-8:  EKKYLWGFTL (SEQ ID NO.: 12)  
RPI-9:  VLATKLRETNAGRCDTROQYRKLLK (SEQ ID NO.: 13)

These fragments were synthesized and purified by HPLC according to the method of Keutmann et al., (Endocrinology 117: 1230, 1984).

EXPRESSION OF POLYPEPTIDES

5            Polypeptides according to the invention may be produced by expression from a recombinant nucleic acid having a sequence encoding part or all of a cell receptor of the invention, using any appropriate expression system: e.g., transformation of a suitable host cell (either  
10           prokaryotic or eukaryotic) with the recombinant nucleic acid in a suitable expression vehicle (e.g., pCDNAI). The precise host cell used is not critical to the invention; however, in the case wherein the polypeptides of the invention include all or part of the PTH/PTHrP receptor, the  
15           following host cells are preferred: COS cells, LLC-PK1 cells, OK cells, AtT20 cells, and CHO cells. The method of transfection and the choice of expression vehicle will depend on the host system selected. Mammalian cell transfection methods are described, e.g., in Ausubel et al.  
20           (Current Protocols in Molecular Biology, John Wiley & Sons, New York, 1989); expression vehicles may be chosen from those discussed, e.g., in Cloning Vectors: A Laboratory Manual (P.H. Pouwels et al., 1985, Supp. 1987). Stably transfected cells are produced via integration of receptor  
25           DNA into the host cell chromosomes. Suitable DNAs are inserted into pCDNA, pCDNAI-Neo, or another suitable plasmid, and then cells are transfected with this plasmid with or without cotransfection with psV-2-Neo, or psV-2-DHFR by standard electroporation, calcium phosphate, and/or  
30           DEAE/Dextran techniques. Selection of transfected cells is performed using progressively increasing levels of G418 (Geneticin, GIBCO), and if necessary, methotrexate.

DNA sequences encoding the polypeptides of the invention can also be expressed in a prokaryotic host cell. DNA encoding a cell receptor or receptor fragment is carried on a vector operably linked to control signals capable of effecting expression in the prokaryotic host. If desired, the coding sequence may contain, at its 5' end, a sequence encoding any of the known signal sequences capable of effecting secretion of the expressed protein into the periplasmic space of the host cell, thereby facilitating recovery of the protein and subsequent purification. Prokaryotes most frequently used are various strains of E. coli; however, other microbial strains may also be used. Plasmid vectors are used which contain replication origins, selectable markers, and control sequences derived from a species compatible with the microbial host. For example, E. coli may be transformed using derivatives of pBR322, a plasmid constructed by Bolivar et al. (Gene 2: 95, 1977) using fragments derived from three naturally-occurring plasmids, two isolated from species of Salmonella, and one isolated from E. coli. pBR322 contains genes from ampicillin and tetracycline resistance, and thus provides multiple selectable markers which can be either retained or destroyed in constructing the desired expression vector. Commonly used prokaryotic control sequences (also referred to as "regulatory elements") are defined herein to include promoters for transcription initiation, optionally with an operator, along with ribosome binding site sequences. Promoters commonly used to direct protein expression include the beta-lactamase (penicillinase), the lactose (lac) (Chang et al., Nature 198: 1056, 1977) and the tryptophan (Trp) promoter systems (Goeddel et al., Nucl. Acids Res. 8: 4057, 1980) as well as the lambda-derived P<sub>L</sub> promoter and N-gene

ribosome binding site (Simatake et al., Nature 292:128, 1981).

5 The nature of the cell receptor proteins of the invention is such that, upon expression within a cell, it is moved to the cellular membrane and partially through the membrane, so that part of it remains embedded in the membrane, part extends outside the cell, and part remains within the cell. Transformed cells bearing such embedded cell receptors may themselves be employed in the methods of  
10 the invention, or the receptor protein may be extracted from the membranes and purified.

15 Expression of peptide fragments lacking the hydrophobic portions of the protein responsible for anchoring the intact protein in the cellular membrane would not be expected to become embedded in the membrane; whether they remain within the cell or are secreted into the extracellular medium depends upon whether or not a mechanism promoting secretion (e.g., a signal peptide) is included. If secreted, the polypeptide of the invention can be  
20 harvested from the medium; if not, the cells must be broken open and the desired polypeptide isolated from the entire contents of the cells. Specific examples of polypeptides which might be expressed include, without limitation:

25 1) Amino-terminal portion comprising amino acids 1-192, including the putative leader sequence, of the rat bone PTH/PTHrP receptor as shown in Fig. 3.

2) Amino-terminal portion comprising amino acids 27-192, excluding the putative leader sequence, of the rat bone PTH/PTHrP receptor as shown in Fig. 3.

30 3) The full-length PTH/PTHrP receptor from rat bone, as shown in Fig 3.

4) RP-1 (as described above).

5) RP-2 (as described above).

The polypeptide of the invention can be readily purified using affinity chromatography. Antibodies to these polypeptides, or the receptor specific ligands, (e.g., the hormones PTH and PTHrP for the PTH/PTHrP receptor) may be covalently coupled to a solid phase support such as Sepharose 4 CNBr-activated sepharose (Pharmacia), and used to separate the polypeptide of the invention from any contaminating substances. Typically 1 mg of ligand or antibody will be incubated with CNBr-activated sepharose at 4°C for 17-20 h (with shaking). The sepharose is rinsed with 1 M Tris HCL (pH8) to block excess active sites. The sepharose-PTH, sepharose-PTHrP, or sepharose-antibody is then incubated with the crude polypeptide in phosphate-buffered saline (pH 7.4) at 4°C for 2 h (with shaking). The sepharose is then typically packed in a column, thoroughly washed with PBS (typically 10 times the column volume), and eluted with dilute HCL in H<sub>2</sub>O (pH 1.85). The eluate may then be concentrated by lyophilization and its purity checked, for example, by reverse phase HPLC.

#### ANTI-CELL RECEPTOR ANTIBODIES

Cell receptor or receptor fragments of the invention may be used to generate antibodies by any conventional method well known to those skilled in the art, including those which generate polyclonal antibodies and those which generate monoclonal antibodies. For example, the deduced amino acid sequence of the PTH receptor reveals a protein structure that appears to have several transmembrane (i.e., hydrophobic) domains interspersed with presumably extracellular and intracellular regions (see Fig. 21) analogous to those found in other G protein-linked receptors. This information can be used to guide the selection of regions of the receptor protein which would be

likely to be exposed on the cell surface, and thus would be presented to antibodies in vivo. A short peptide representing one or more of such regions may be synthesized (e.g., chemically or by recombinant DNA techniques) and used to immunize an animal (e.g., a rabbit or a mouse) to generate polyclonal or monoclonal antibodies. For example, certain of the peptides of the PTH/PTHrP receptor listed above (RP-1, RP-5 and RP-6) have been chemically synthesized using standard techniques and used to generate polyclonal antibodies in rabbits by the following procedure:

A preparation of a given peptide emulsified with complete Freund's Adjuvant is injected intradermally into rabbits. Booster injections are emulsified in or complete adjuvant and injected at monthly intervals.

Antibody titer is assessed using either of two methods. First, serial dilutions of the antiserum in 1% normal rabbit serum are incubated with  $^{125}\text{I}$ -labelled PTH/PTHrP receptor fragment by standard methods (e.g., see Segre et al., supra) for 24 h at 4° C. The bound  $^{125}\text{I}$ -PTH/PTHrP receptor fragments are separated from unbound by addition of 100  $\mu\text{l}$  of second antibody (anti-rabbit IgG, Sigma) diluted 1:20 and 1 ml of 5% polyethylene glycol, followed by centrifugation at 2000 rpm for 30 min. at 4° C. The supernatant is removed and the pellet analyzed for radioactivity in a  $\gamma$ -counter. In the second method, cell lines expressing either native (e.g., ROS 17/2.8, OK, SaOS-02 cells) or recombinant (COS cells or CHO cells transfected with R15B, OK-O or OK-H) PTH/PTHrP receptors are incubated with serially diluted antibody at 4°C, 20°C or 37°C for 1- 4 h. The cells are rinsed with PBS (x3) and incubated for 2 h at 4°C with  $^{125}\text{I}$ -labelled (NEN, Dupont) or FITC-labelled (Sigma) second antibodies. After rinsing (x3 with

PBS), the cells were either lysed with 0.1 M NaOH and counted in  $\gamma$ -counter (if  $^{125}\text{I}$ -labelled second antibody was used) or fixed with 1% paraformaldehyde and examined by fluorescent microscopy (if FITC-labelled second antibody was used).

Another method for producing antibodies utilizes as antigen the intact cell receptor protein of the invention expressed on the surface of cells (e.g., mammalian cells, such as COS cells, transfected with DNA encoding the receptor). Such cells are prepared by standard techniques, e.g., by the DEAE-dextran transfection method, using a vector encoding and capable of directing high-level expression of the cell receptor. Such cells may be used to generate polyclonal or monoclonal antibodies. For example, monoclonal antibodies specific for the PTH/PTHrP receptor may be produced by the following procedure:

Intact COS cells expressing high levels of rat recombinant PTH receptors on the cell surface are injected intraperitoneally (IP) into Balb-c mice (Charles River Laboratories, Willmington, MA). The mice are boosted every 4 weeks by IP injection, and are hyperimmunized by an intravenous (IV) booster 3 days before fusion. Spleen cells from the mice are isolated and are fused by standard methods to myeloma cells. Hybridomas are selected in standard hypoxanthine/aminopterin/thymine (HAT) medium, according to standard methods. Hybridomas secreting antibodies which recognize the PTH receptor are initially identified by screening with cell lines which naturally express abundant copies of the PTH-receptor per cell (such as ROS17/2.8 or OK cells), using standard immunological techniques. Those hybridomas which produce antibodies capable of binding to the PTH receptor are cultured and subcloned. Secondary



screening with radioreceptor and cAMP stimulation assays can then be performed to further characterize the monoclonal antibodies (see below).

SCREENING FOR PTH RECEPTOR ANTAGONISTS AND AGONISTS

5           The polypeptides and antibodies of the invention and other compounds may be screened for PTH-competition and for antagonistic or agonistic properties using the assays described herein.

10           In one example, those antibodies that recognize the PTH receptor on the intact cells are screened for their ability to compete with PTH or PTHrP for binding to a PTH/PTHrP receptor. Cells expressing PTH receptor on the cell surface are incubated with the <sup>125</sup>I-PTH analog, <sup>125</sup>I-NlePTH or <sup>125</sup>I-PTHrP in the presence or absence of the  
15 polyclonal or monoclonal antibody to be tested, for 4 h at 15°C. The antibody used may be from crude antiserum, cell medium, or ascites, or in purified form. After incubation, the cells are rinsed with binding buffer (e.g., physiological saline), lysed, and quantitatively analyzed  
20 for radioactivity using a gamma-counter. Antibodies that reduce binding of the PTH analog to the PTH receptor are classified as competitive; those which do not are noncompetitive.

25           Compounds, including antibodies and polypeptides, may be screened for their agonistic or antagonistic properties using the cAMP accumulation, intracellular calcium, and/or inositol phosphate assays described above. Cells expressing PTH receptor on the cell surface are  
30 incubated with PTH, PTH-receptor antibody, or a combination of both, for 5 - 60 minutes at 37°C, in the presence of 2 mM IBMX (3-isobutyl-1-methyl-xanthine, Sigma, St. Louis, MO). Cyclic AMP accumulation is measured by specific radio-

immunoassay, as described above. A compound that competes with PTH for binding to the PTH receptor, and that inhibits the effect of PTH on cAMP accumulation, is considered a competitive PTH antagonist. Conversely, a compound that does not compete for PTH binding to the PTH receptor, but which still prevents PTH activation of cAMP accumulation (presumably by blocking the receptor activation site) is considered a non-competitive antagonist. A compound that competes with PTH for binding to the PTH receptor, and which stimulates cAMP accumulation in the presence or absence of PTH, is a competitive agonist. A compound that does not compete with PTH for binding to the PTH receptor but which is still capable of stimulating cAMP accumulation in the presence or absence of PTH, or which stimulates a higher accumulation than that observed by PTH alone, would be considered a non-competitive agonist.

#### USE

The polypeptides, antibodies, and other compounds of the invention are useful for the diagnosis, classification, prognosis, and/or treatment of disorders which may be characterized as related to the interaction between a cell receptor of the invention and its specific ligand. For example, some forms of hypercalcemia and hypocalcemia are related to the interaction between PTH and PTHrP and the PTH/PTHrP receptor(s). Hypercalcemia is an condition in which there is an abnormal elevation in serum calcium level; it is often associated with other diseases, including hyperparathyroidism, osteoporosis, carcinomas of the breast, lung and prostate, epidermoid cancers of the head and neck of the esophagus, multiple myeloma, and hypernephroma. Hypocalcemia, a condition in which the serum calcium level is abnormally low, may result from a deficiency of effective PTH, e.g., following thyroid surgery.

In a first example, the compounds of the invention are used to manufacture diagnostic agents which are used as diagnostic tools to diagnose hypercalcemia and to distinguish between hypercalcemic conditions, i.e., to differentiate hypercalcemia mediated by PTH or PTHrP (e.g., hyperparathyroidism and humoral hypercalcemia of malignancy), from hypercalcemia associated with diseases which do not involve these factors (e.g., local osteolytic hypercalcemia mediated by the presence of metastatic tumor cells in direct contact with bone, and certain rare types of malignancy-related hypercalcemias mediated by an increase of humoral factors, such as osteoclast activating factor (interleukin), lymphotoxin, calcitriol, type E prostaglandins, and vitamin D-like sterols).

In one method of diagnosis, serum total and/or ionized calcium levels are measured by standard techniques before and after the administration of the PTH or PTHrP antagonists of the invention. PTH or PTHrP related hypercalcemias would be detectable as a decrease in serum calcium levels following administration of the antagonist of the invention. In contrast, for hypercalcemic conditions mediated by factors other than PTH or PTHrP, the serum calcium levels would remain unchanged even after administration of the antagonist.

Another diagnostic application of the invention permits measurement of the level of PTH or PTHrP in a biological sample in order to diagnose PTH or PTHrP related tumors, e.g., tumors which are associated with humoral hypercalcemia of malignancy, and for monitoring the levels of PTH or PTHrP during cancer therapy. This method involves assaying binding of the recombinant parathyroid hormone receptor of the invention to PTH or PTHrP present in a tissue sample, using the binding assay described herein.

The level of binding may be determined directly (e.g., by using radioactively labelled PTH receptor, and assaying the radioactivity bound to endogenous PTH). Alternatively, binding of PTH receptor to the sample (e.g., a tissue section) may be followed by staining of the tissue sections with an antibody specific for the PTH receptor, using standard immunological techniques (Chin et al., Hybridoma 5:339, 1986).

In a third diagnostic approach, one could stably transfect cell lines (by the methods described in Ausubel et al., Current Protocols in Molecular Biology, Wiley Publishers, New York, 1987) with a PTH receptor gene linked to an appropriate promoter (e.g., the metallothionine promoter). Alternatively, the PTH/PTHrP receptor could be expressed from a eukaryotic vector, i.e., pcDNAI, and cotransfected with a mutant DHFR gene that will allow further gene amplification via methotrexate selection (Simonsen et al., Proc. Natl. Acad. Sci., 80:2495-2499, 1983). Such high-level expression of the gene produces an immortal cell line which is oversensitive to PTH or PTHrP. Such cells provide a particularly useful tool for detecting serum blood levels of PTH or PTHrP. Such a cell line may be used for diagnosis of conditions involving elevated PTH or PTHrP levels (e.g., those described above) or for conditions involving unusually low levels of PTH or PTHrP (e.g., those described above). Such a cell line is also useful for monitoring the regression or increase of PTH or PTHrP levels during therapy for hypercalcemia or hypocalcemia, respectively.

A patient who is suspected of being hypercalcemic may be treated using the compounds of the invention. Rapid intervention is important because symptoms may appear abruptly and, unless reversed, can be fatal. In one

application, serum calcium levels are stabilized by an immediate course of treatment which includes antagonists of PTH or PTHrP. Such antagonists include the compounds of the invention which have been determined (by the assays described herein) to interfere with PTH receptor-mediated cell activation. To administer the antagonist, the appropriate antibody or peptide (is used in the manufacture of a medicament, generally by being formulated in an appropriate carrier such as physiological saline, and administered intravenously, at a dosage that provides adequate competition for PTH or PTHrP binding to the PTH receptor (e.g., a dosage sufficient to lower the serum calcium level to below 10 mg/dl). Typical dosage would be 1 ng to 10 mg of the antibody or peptide per kg body weight per day. Treatment may be repeated as necessary for long term maintenance of acceptable calcium levels (i.e., levels < 10.1 mg/dl). This may be necessary for acute treatment of an underlying disease condition triggering hypercalcemia; or it may be used, e.g., for chronic treatment of conditions such as osteoporosis.

In another application, the compounds of the invention which have been characterized, according to the methods of the invention, to be agonists are used therapeutically to treat hypocalcemia: e.g., that resulting from the partial or complete surgical removal of the parathyroid glands. Agonists may be formulated in a suitable carrier (e.g., physiological saline) and are preferably administered intravenously in a dosage that causes a rise in serum calcium to an acceptable level (i.e., approximately 8 mg/dl). A useful dosage range would be 1 ng to 10 mg of the agonist per kg body weight per day. Treatment may be repeated as necessary to maintain suitable

serum calcium levels; long term treatment may be necessary for patients who have undergone parathyroid gland removal.

The nucleic acids of the invention may also be used therapeutically. Oligonucleotides which are antisense to PTH receptor mRNA (or nucleic acid constructs which express RNA that is antisense to PTH receptor mRNA) may be utilized as an anticancer therapy. This approach is useful, e.g., for hypercalcemias resulting from a genomic rearrangement or amplification which increases the amount or activity of PTH receptor, PTH or PTHrP. The method would involve introduction of the antisense oligonucleotide into the tumor cells *in vivo*. The antisense strand hybridizes with endogenous PTH receptor mRNA, interfering with translation of the protein, thereby reducing production of PTH receptor in such cells, and reducing PTH/PTHrP-associated neoplastic growth. Methods for antisense design and introduction into host cells are described, for example, in Weinberg et al., U.S. Patent No. 4,740,463, herein incorporated by reference.

The biochemical characterization of the OK-H, OK-O and R15B PTH/PTHrP receptors of the invention demonstrate that the two transduction pathways now known to be triggered by the interaction of PTH with its receptor are distinct and may be separated. The predicted amino acid sequences of these receptors indicate that OK-H, which does not appear to activate inositol phosphate metabolism to any detectable degree, is 70 amino acids shorter at the carboxy-terminus than OK-O or R15B. By using the sequences of the invention and the information disclosed herein, one could clone and then alter (e.g. by site-directed mutagenesis) PTH/PTHrP receptor genes from any species to generate PTH/PTHrP receptors which do not activate phospholipase C. This could potentially allow the separation of different PTH-mediated actions, including bone resorption and bone formation, and

could of great importance for the treatment of various bone disorders such as osteoporosis.

5 Nucleic acids of the invention which encode a PTH receptor may also be linked to a selected tissue-specific promoter and/or enhancer and the resultant hybrid gene introduced, by standard methods (e.g., as described by Leder et al., U.S. Patent No. 4,736,866, herein incorporated by reference), into an animal embryo at an early developmental stage (e.g., the fertilized oocyte stage), to produce a  
10 transgenic animal which expresses elevated levels of PTH receptor in selected tissues (e.g., the osteocalcin promoter for bone). Such promoters are used to direct tissue-specific expression of the PTH receptor in the transgenic animal. The form of PTH receptor utilized can be  
15 one which encodes a PTH receptor similar to that of the animal species used, or it can encode the PTH receptor homolog of a different species. In one particular example, transgenic chickens are engineered to express the PTH receptor from a promoter which directs high-level expression in chicken oviducts. Such an animal is expected to produce  
20 eggs with higher calcium content, and thus harder shells.

#### Other Embodiments

Other embodiments are within the following claims. For example, the nucleic acid of the invention includes  
25 genes or cDNAs or RNAs originally isolated from any vertebrate species, including birds or mammals such as marsupials, rodents, or humans. The high degree of homology demonstrated for the PTH receptors from such diverse species as opossum, rat, and human indicates that the methods of  
30 isolating PTH receptors disclosed herein will be broadly applicable to the isolation of related cell receptors from a wide variety of species.

COMPUTER SUBMISSION OF DNA AND AMINO ACID SEQUENCES

(1) GENERAL INFORMATION:

- (i) APPLICANT: Segre, Gino V.  
Kronenberg, Henry M.  
Abou-Samra, Abdul-Badi  
Juppner, Harald  
Potts, John T., Jr.  
Schipani, Ernestina
- (ii) TITLE OF INVENTION: PARATHYROID HORMONE RECEPTOR AND DNA  
ENCODING SAME
- (iii) NUMBER OF SEQUENCES: 3
- (iv) CORRESPONDENCE ADDRESS:
- (A) ADDRESSEE: Fish & Richardson  
(B) STREET: 225 Franklin Street  
(C) CITY: Boston  
(D) STATE: Massachusetts  
(E) COUNTRY: U.S.A.  
(F) ZIP: 02110-2804
- (v) COMPUTER READABLE FORM:
- (A) MEDIUM TYPE: 3.5" Diskette, 1.44 Mb storage  
(B) COMPUTER: IBM PS/2 Model 50Z or 55SX  
(C) OPERATING SYSTEM: IBM P.C. DOS (Version 3.30)  
(D) SOFTWARE: WordPerfect (Version 5.0)
- (vi) CURRENT APPLICATION DATA:
- (A) APPLICATION NUMBER:  
(B) FILING DATE:  
(C) CLASSIFICATION:
- (vii) PRIOR APPLICATION DATA:
- (A) APPLICATION NUMBER: 07/681,702  
(B) FILING DATE: April 5, 1991
- (viii) ATTORNEY/AGENT INFORMATION:
- (A) NAME: Paul T. Clark  
(B) REGISTRATION NUMBER: 30,162  
(C) REFERENCE/DOCKET NUMBER: 00786/071001



(ix) TELECOMMUNICATION INFORMATION:

(A) TELEPHONE: (617) 542-5070  
 (B) TELEFAX: (617) 542-8906  
 (C) TELEX: 200154

(2) INFORMATION FOR SEQUENCE IDENTIFICATION NUMBER: 1:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 1862  
 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: double  
 (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQUENCE ID NO: 1:

TGGGCACAGC CACCCTGTTG GTAGTCCAGG GGCCAGCCCA CTGAGCTGGC ATATCAGCTG	60
GTGGCCCCGT TGGACTCGGC CCTAGGGAAC GGCGGCG ATG GGA GCG CCC CGG ATC	115
	Met Gly Ala Pro Arg Ile
	1 5
TCG CAC AGC CTT GCC TTG CTC CTC TGC TGC TCC GTG CTC AGC TCC GTC	163
Ser His Ser Leu Ala Leu Leu Leu Cys Cys Ser Val Leu Ser Ser Val	
	10 15 20
TAC GCA CTG GTG GAT GCC GAT GAT GTC ATA ACG AAG GAG GAG CAG ATC	211
Tyr Ala Leu Val Asp Ala Asp Asp Val Ile Thr Lys Glu Glu Gln Ile	
	25 30 35
ATT CTT CTG CGC AAT GCC CAG GCC CAG TGT GAG CAG CGC CTG AAA GAG	259
Ile Leu Leu Arg Asn Ala Gln Ala Gln Cys Glu Gln Arg Leu Lys Glu	
	40 45 50
GTC CTC AGG GTC CCT GAA CTT GCT GAA TCT GCC AAA GAC TGG ATG TCA	307
Val Leu Arg Val Pro Glu Leu Ala Glu Ser Ala Lys Asp Trp Met Ser	
	55 60 65 70
AGG TCT GCA AAG ACA AAG AAG GAG AAA CCT GCA GAA AAG CTT TAT CCC	355
Arg Ser Ala Lys Thr Lys Lys Glu Lys Pro Ala Glu Lys Leu Tyr Pro	
	75 80 85
CAG GCA GAG GAG TCC AGG GAA GTT TCT GAC AGG AGC CGG CTG CAG GAT	403
Gln Ala Glu Glu Ser Arg Glu Val Ser Asp Arg Ser Arg Leu Gln Asp	
	90 95 100

66442277 42366460

GGC Gly	TTC Phe	TGC Cys 105	CTA Leu	CCT Pro	GAG Glu	TGG Trp	GAC Asp 110	AAC Asn	ATT Ile	GTG Val	TGC Cys	TGG Trp 115	CCT Pro	GCT Ala	GGA Gly	451
GTG Val	CCC Pro 120	GGC Gly	AAG Lys	GTG Val	GTG Val	GCC Ala 125	GTG Val	CCC Pro	TGC Cys	CCC Pro	GAC Asp 130	TAC Tyr	TTC Phe	TAC Tyr	GAC Asp	499
TTC Phe 135	AAC Asn	CAC His	AAA Lys	GGC Gly	CGA Arg 140	GCC Ala	TAT Tyr	CGG Arg	CGC Arg	TGT Cys 145	GAC Asp	AGC Ser	AAT Asn	GGC Gly	AGC Ser 150	547
TGG Trp	GAG Glu	CTG Leu	GTG Val	CCT Pro 155	GGG Gly	AAC Asn	AAC Asn	CGG Arg	ACA Thr 160	TGG Trp	GCG Ala	AAT Asn	TAC Tyr	AGC Ser 165	GAA Glu	595
TGT Cys	GTC Val	AAG Lys 170	TTT Phe	CTG Leu	ACC Thr	AAC Asn	GAG Glu	ACC Thr 175	CGG Arg	GAA Glu	CGG Arg	GAA Glu 180	GTC Val	TTT Phe	GAT Asp	643
CGC Arg	CTC Leu	GGA Gly 185	ATG Met	ATC Ile	TAC Tyr	ACT Thr	GTG Val 190	GGC Gly	TAC Tyr	TCC Ser	ATC Ile	TCT Ser 195	CTG Leu	GGC Gly	TCC Ser	691
CTC Leu	ACT Thr 200	GTG Val	GCT Ala	GTG Val	CTG Leu	ATT Ile 205	CTG Leu	GGT Gly	TAC Tyr	TTT Phe 210	AGG Arg	AGG Arg	TTA Leu	CAT His	TGC Cys	739
ACC Thr 215	CGA Arg	AAC Asn	TAC Tyr	ATT Ile	CAC His 220	ATG Met	CAT His	CTC Leu	TTC Phe	GTG Val 225	TCC Ser	TTT Phe	ATG Met	CTC Leu	CGG Arg 230	787
GCT Ala	GTA Val	AGC Ser	ATC Ile	TTC Phe 235	ATC Ile	AAG Lys	GAT Asp	GCT Ala	GTG Val 240	CTC Leu	TAC Tyr	TCG Ser	GGG Gly 245	GTT Val	TCC Ser	835
ACA Thr	GAT Asp	GAA Glu 250	ATC Ile	GAG Glu	CGC Arg	ATC Ile	ACC Thr 255	GAG Glu	GAG Glu	GAG Glu	CTG Leu	AGG Arg 260	GCC Ala	TTC Phe	ACA Thr	883
GAG Glu	CCT Pro 265	CCC Pro	CCT Pro	GCT Ala	GAC Asp	AAG Lys 270	GCG Ala	GGT Gly	TTT Phe	GTG Val	GGC Gly 275	TGC Cys 275	AGA Arg	GTG Val	GCG Ala	931
GTA Val 280	ACC Thr	GTC Val	TTC Phe	CTT Leu	TAC Tyr	TTC Phe 285	CTG Leu	ACC Thr	ACC Thr	AAC Asn	TAC Tyr 290	TAC Tyr	TGG Trp	ATC Ile	CTG Leu	979

GTG Val 295	GAA Glu	GGC Gly	CTC Leu	TAC Tyr	CTT Leu 300	CAC His	AGC Ser	CTC Leu	ATC Ile	TTC Phe 305	ATG Met	GCT Ala	TTT Phe	TTC Phe	TCT Ser 310	1027
GAG Glu	AAA Lys	AAG Lys	TAT Tyr	CTC Leu 315	TGG Trp	GGT Gly	TTC Phe	ACA Thr	TTA Leu 320	TTT Phe	GGC Gly	TGG Trp	GGC Gly	CTC Leu 325	CCT Pro	1075
GCC Ala	GTG Val	TTT Phe	GTC Val 330	GCT Ala	GTG Val	TGG Trp	GTG Val	ACC Thr 335	GTG Val	AGG Arg	GCT Ala	ACA Thr	CTG Leu 340	GCC Ala	AAC Asn	1123
ACT Thr	GAG Glu	TGC Cys 345	TGG Trp	GAC Asp	CTG Leu	AGT Ser	TCG Ser 350	GGG Gly	AAT Asn	AAG Lys	AAA Lys	TGG Trp 355	ATC Ile	ATA Ile	CAG Gln	1171
GTG Val 360	CCC Pro	ATC Ile	CTG Leu	GCA Ala	GCT Ala 365	ATT Ile	GTG Val	GTG Val	AAC Asn	TTT Phe	ATT Ile 370	CTT Leu	TTT Phe	ATC Ile	AAT Asn	1219
ATA Ile 375	ATC Ile	AGA Arg	GTC Val	CTG Leu 380	GCT Ala	ACT Thr	AAA Lys	CTC Leu	CGG Arg	GAG Glu 385	ACC Thr	AAT Asn	GCA Ala	GGG Gly	AGA Arg 390	1267
TGT Cys	GAC Asp	ACG Thr	AGG Arg	CAA Gln 395	CAG Gln	TAT Tyr	AGA Arg	AAG Lys	CTG Leu 400	CTG Leu	AAG Lys	TCC Ser	ACG Thr	CTA Leu 405	GTC Val	1315
CTC Leu	ATG Met	CCG Pro	CTA Leu 410	TTT Phe	GGG Gly	GTG Val	CAC His	TAC Tyr 415	ATC Ile	GTC Val	TTC Phe	ATG Met	GCC Ala 420	ACG Thr	CCG Pro	1363
TAC Tyr	ACA Thr	GAA Glu 425	GTA Val	TCA Ser	GGG Gly	ATT Ile	CTT Leu 430	TGG Trp	CAA Gln	GTC Val	CAA Gln	ATG Met 435	CAC His	TAT Tyr	GAA Glu	1411
ATG Met 440	CTC Leu	TTC Phe	AAT Asn	TCA Ser	TTC Phe 445	CAG Gln	GGA Gly	TTT Phe	TTC Phe	GTT Val	GCC Ala 450	ATT Ile	ATA Ile	TAC Tyr	TGT Cys	1459
TTC Phe 455	TGC Cys	AAT Asn	GGA Gly	GAG Glu	GTA Val 460	CAA Gln	GCA Ala	GAG Glu	ATC Ile	AAG Lys 465	AAG Lys	TCA Ser	TGG Trp	AGC Ser	CGA Arg 470	1507
TGG Trp	ACC Thr	CTG Leu	GCC Ala	TTG Leu 475	GAC Asp	TTC Phe	AAG Lys	CGG Arg	AAG Lys 480	GCC Ala	CGG Arg	AGT Ser	GGC Gly	AGC Ser 485	AGT Ser	1555

GGA CCT CGA GGG GGC TGG CCT TGT CCC TCA GCC CTC GAC TAGCTCCTGG 1652  
Gly Pro Arg Gly Gly Trp Pro Cys Pro Ser Ala Leu Asp  
505 510 515

(2) INFORMATION FOR SEQUENCE IDENTIFICATION NUMBER: 2:

(A) LENGTH: 1863  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear

TTGGGCACAGC	CACCCCTGTTG	GTAGTCCAGG	GGCCAGCCCA	CTGAGCTGGC	ATATCAGCTG	60
GTGGCCCCGT	TGGA	CTCGGC	CCTAGGGAAC	GGCGGCG	ATG GGA GCG CCC CGG ATC	115
					Met Gly Ala Pro Arg Ile	
					1 5	
TCG CAC AGC CTT GCC TTG CTC CTC TGC TGC TCC GTG CTC AGC TCC GTC	163					
Ser His Ser Leu Ala Leu Leu Leu Cys Cys Ser Val Leu Ser Ser Val						
10 15 20						
TAC GCA CTG GTG GAT GCC GAT GAT GTC ATA ACG AAG GAG GAG CAG ATC	211					
Tyr Ala Leu Val Asp Ala Asp Asp Val Ile Thr Lys Glu Glu Gln Ile						
25 30 35						
ATT CTT CTG CGC AAT GCC CAG GCC CAG TGT GAG CAG CGC CTG AAA GAG	259					
Ile Leu Leu Arg Asn Ala Gln Ala Gln Cys Glu Gln Arg Leu Lys Glu						
40 45 50						
GTC CTC AGG GTC CCT GAA CTT GCT GAA TCT GCC AAA GAC TGG ATG TCA	307					
Val Leu Arg Val Pro Glu Leu Ala Glu Ser Ala Lys Asp Trp Met Ser						
55 60 65 70						



GAG	CCT	CCC	CCT	GCT	GAC	AAG	GCG	GGT	TTT	GTG	GGC	TGC	AGA	GTG	GCG	931
Glu	Pro	Pro	Pro	Ala	Asp	Lys	Ala	Gly	Phe	Val	Gly	Cys	Arg	Val	Ala	
		265					270					275				
GTA	ACC	GTC	TTC	CTT	TAC	TTC	CTG	ACC	ACC	AAC	TAC	TAC	TGG	ATC	CTG	979
Val	Thr	Val	Phe	Leu	Tyr	Phe	Leu	Thr	Thr	Asn	Tyr	Tyr	Trp	Ile	Leu	
	280					285					290					
GTG	GAA	GGC	CTC	TAC	CTT	CAC	AGC	CTC	ATC	TTC	ATG	GCT	TTT	TTC	TCT	1027
Val	Glu	Gly	Leu	Tyr	Leu	His	Ser	Leu	Ile	Phe	Met	Ala	Phe	Phe	Ser	
	295				300					305					310	
GAG	AAA	AAG	TAT	CTC	TGG	GGT	TTC	ACA	TTA	TTT	GGC	TGG	GGC	CTC	CCT	1075
Glu	Lys	Lys	Tyr	Leu	Trp	Gly	Phe	Thr	Leu	Phe	Gly	Trp	Gly	Leu	Pro	
				315					320					325		
GCC	GTG	TTT	GTC	GCT	GTG	TGG	GTG	ACC	GTG	AGG	GCT	ACA	CTG	GCC	AAC	1123
Ala	Val	Phe	Val	Ala	Val	Trp	Val	Thr	Val	Arg	Ala	Thr	Leu	Ala	Asn	
			330					335					340			
ACT	GAG	TGC	TGG	GAC	CTG	AGT	TCG	GGG	AAT	AAG	AAA	TGG	ATC	ATA	CAG	1171
Thr	Glu	Cys	Trp	Asp	Leu	Ser	Ser	Gly	Asn	Lys	Lys	Trp	Ile	Ile	Gln	
		345					350					355				
GTG	CCC	ATC	CTG	GCA	GCT	ATT	GTG	GTG	AAC	TTT	ATT	CTT	TTT	ATC	AAT	1219
Val	Pro	Ile	Leu	Ala	Ala	Ile	Val	Val	Asn	Phe	Ile	Leu	Phe	Ile	Asn	
	360					365					370					
ATA	ATC	AGA	GTC	CTG	GCT	ACT	AAA	CTC	CGG	GAG	ACC	AAT	GCA	GGG	AGA	1267
Ile	Ile	Arg	Val	Leu	Ala	Thr	Lys	Leu	Arg	Glu	Thr	Asn	Ala	Gly	Arg	
	375				380					385					390	
TGT	GAC	ACG	AGG	CAA	CAG	TAT	AGA	AAG	CTG	CTG	AAG	TCC	ACG	CTA	GTC	1315
Cys	Asp	Thr	Arg	Gln	Gln	Tyr	Arg	Lys	Leu	Leu	Lys	Ser	Thr	Leu	Val	
				395					400					405		
CTC	ATG	CCG	CTA	TTT	GGG	GTG	CAC	TAC	ATC	GTC	TTC	ATG	GCC	ACG	CCG	1363
Leu	Met	Pro	Leu	Phe	Gly	Val	His	Tyr	Ile	Val	Phe	Met	Ala	Thr	Pro	
			410					415					420			
TAC	ACA	GAA	GTA	TCA	GGG	ATT	CTT	TGG	CAA	GTC	CAA	ATG	CAC	TAT	GAA	1411
Tyr	Thr	Glu	Val	Ser	Gly	Ile	Leu	Trp	Gln	Val	Gln	Met	His	Tyr	Glu	
		425					430					435				
ATG	CTC	TTC	AAT	TCA	TTC	CAG	GGA	TTT	TTC	GTT	GCC	ATT	ATA	TAC	TGT	1459
Met	Leu	Phe	Asn	Ser	Phe	Gln	Gly	Phe	Phe	Val	Ala	Ile	Ile	Tyr	Cys	
	440					445					450					

TTC	TGC	AAT	GGA	GAG	GTA	CAA	GCA	GAG	ATC	AAG	AAG	TCA	TGG	AGC	CGA	1507
Phe	Cys	Asn	Gly	Glu	Val	Gln	Ala	Glu	Ile	Lys	Lys	Ser	Trp	Ser	Arg	
455					460					465					470	
TGG	ACC	CTG	GCC	TTG	GAC	TTC	AAG	CGG	AAG	GCC	CGG	AGT	GGC	AGC	AGT	1555
Trp	Thr	Leu	Ala	Leu	Asp	Phe	Lys	Arg	Lys	Ala	Arg	Ser	Gly	Ser	Ser	
				475					480					485		
ACC	TAC	AGC	TAT	GGC	CCC	ATG	GTG	TCA	CAT	ACA	AGT	GTC	ACC	AAT	GTG	1603
Thr	Tyr	Ser	Tyr	Gly	Pro	Met	Val	Ser	His	Thr	Ser	Val	Thr	Asn	Val	
				490				495					500			
GGA	CCT	CGA	GGG	GGG	CTG	GCC	TTG	TCC	CTC	AGC	CCT	CGA	CTA	GCT	CCT	1651
Gly	Pro	Arg	Gly	Gly	Leu	Ala	Leu	Ser	Leu	Ser	Pro	Arg	Leu	Ala	Pro	
		505					510					515				
GGG	GCT	GGA	GCC	AGT	GCC	AAT	GGC	CAT	CAC	CAG	TTG	CCT	GGC	TAT	GTG	1699
Gly	Ala	Gly	Ala	Ser	Ala	Asn	Gly	His	His	Gln	Leu	Pro	Gly	Tyr	Val	
	520					525					530					
AAG	CAT	GGT	TCC	ATT	TCT	GAG	AAC	TCA	TTG	CCT	TCA	TCT	GGC	CCA	GAG	1747
Lys	His	Gly	Ser	Ile	Ser	Glu	Asn	Ser	Leu	Pro	Ser	Ser	Gly	Pro	Glu	
535					540					545					550	
CCT	GGC	ACC	AAA	GAT	GAC	GGG	TAT	CTC	AAT	GGC	TCT	GGA	CTT	TAT	GAG	1795
Pro	Gly	Thr	Lys	Asp	Asp	Gly	Tyr	Leu	Asn	Gly	Ser	Gly	Leu	Tyr	Glu	
				555					560					565		
CCA	ATG	GTT	GGG	GAA	CAG	CCC	CCT	CCA	CTC	CTG	GAG	GAG	GAG	AGA	GAG	1843
Pro	Met	Val	Gly	Glu	Gln	Pro	Pro	Pro	Leu	Leu	Glu	Glu	Glu	Arg	Glu	
			570					575					580			
ACA	GTC	ATG	TGACCCATAT	C												1863
Thr	Val	Met														
		585														

(2) INFORMATION FOR SEQUENCE IDENTIFICATION NUMBER: 3:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH:	2051
(B) TYPE:	nucleic acid
(C) STRANDEDNESS:	double
(D) TOPOLOGY:	linear

(xi) SEQUENCE DESCRIPTION: SEQUENCE ID NO: 3:

GGCGGGGGCC	GCGGCGGCGA	GCTCGGAGGC	CGGCGGCGGC	TGCCCCGAGG	GACGCGGCCC	60
TAGGCGGTGG CG ATG GGG GCC GCC CGG ATC GCA CCC AGC CTG GCG CTC						108
Met Gly Ala Ala Arg Ile Ala Pro Ser Leu Ala Leu						
1 5 10						
CTA CTC TGC TGC CCA GTG CTC AGC TCC GCA TAT GCG CTG GTG GAT GCG	156					
Leu Leu Cys Cys Pro Val Leu Ser Ser Ala Tyr Ala Leu Val Asp Ala						
15 20 25						
GAC GAT GTC TTT ACC AAA GAG GAA CAG ATT TTC CTG CTG CAC CGT GCC	204					
Asp Asp Val Phe Thr Lys Glu Glu Gln Ile Phe Leu Leu His Arg Ala						
30 35 40						
CAG GCG CAA TGT GAC AAG CTG CTC AAG GAA GTT CTG CAC ACA GCA GCC	252					
Gln Ala Gln Cys Asp Lys Leu Leu Lys Glu Val Leu His Thr Ala Ala						
45 50 55 60						
AAC ATA ATG GAG TCA GAC AAG GGC TGG ACA CCA GCA TCT ACG TCA GGG	300					
Asn Ile Met Glu Ser Asp Lys Gly Trp Thr Pro Ala Ser Thr Ser Gly						
65 70 75						
AAG CCC AGG AAA GAG AAG GCA TCG GGA AAG TTC TAC CCT GAG TCT AAA	348					
Lys Pro Arg Lys Glu Lys Ala Ser Gly Lys Phe Tyr Pro Glu Ser Lys						
80 85 90						
GAG AAC AAG GAC GTG CCC ACC GGC AGC AGG CGC AGA GGG CGT CCC TGT	396					
Glu Asn Lys Asp Val Pro Thr Gly Ser Arg Arg Arg Gly Arg Pro Cys						
95 100 105						
CTG CCC GAG TGG GAC AAC ATC GTT TGC TGG CCA TTA GGG GCA CCA GGT	444					
Leu Pro Glu Trp Asp Asn Ile Val Cys Trp Pro Leu Gly Ala Pro Gly						
110 115 120						
GAA GTG GTG GCA GTA CCT TGT CCC GAT TAC ATT TAT GAC TTC AAT CAC	492					
Glu Val Val Ala Val Pro Cys Pro Asp Tyr Ile Tyr Asp Phe Asn His						
125 130 135 140						
AAA GGC CAT GCC TAC AGA CGC TGT GAC CGC AAT GGC AGC TGG GAG GTG	540					
Lys Gly His Ala Tyr Arg Arg Cys Asp Arg Asn Gly Ser Trp Glu Val						
145 150 155						
GTT CCA GGG CAC AAC CGG ACG TGG GCC AAC TAC AGC GAG TGC CTC AAG	588					
Val Pro Gly His Asn Arg Thr Trp Ala Asn Tyr Ser Glu Cys Leu Lys						
160 165 170						
TTC ATG ACC AAT GAG ACG CGG GAA CGG GAG GTA TTT GAC CGC CTA GGC	636					
Phe Met Thr Asn Glu Thr Arg Glu Arg Glu Val Phe Asp Arg Leu Gly						
175 180 185						



ATG Met 190	ATC Ile	TAC Tyr	ACC Thr	GTG Val	GGA Gly	TAC Tyr 195	TCC Ser	ATG Met	TCT Ser	CTC Leu	GCC Ala 200	TCC Ser	CTC Leu	ACG Thr	GTG Val	684
GCT Ala 205	GTG Val	CTC Leu	ATC Ile	CTG Leu	GCC Ala 210	TAT Tyr	TTT Phe	AGG Arg	CGG Arg	CTG Leu 215	CAC His	TGC Cys	ACG Thr	CGC Arg	AAC Asn 220	732
TAC Tyr	ATC Ile	CAC His	ATG Met	CAC His 225	ATG Met	TTC Phe	CTG Leu	TCG Ser	TTT Phe 230	ATG Met	CTG Leu	CGC Arg	GCC Ala	GCG Ala 235	AGC Ser	780
ATC Ile	TTC Phe	GTG Val	AAG Lys 240	GAC Asp	GCT Ala	GTG Val	CTC Leu	TAC Tyr 245	TCT Ser	GGC Gly	TTC Phe	ACG Thr	CTG Leu 250	GAT Asp	GAG Glu	828
GCC Ala	GAG Glu 255	CGC Arg	CTC Leu	ACA Thr	GAG Glu	GAA Glu	GAG Glu 260	TTG Leu	CAC His	ATC Ile	ATC Ile	GCG Ala 265	CAG Gln	GTG Val	CCA Pro	876
CCT Pro 270	CCG Pro	CCG Pro	GCC Ala	GCT Ala	GCC Ala	GCC Ala 275	GTA Val	GGC Gly	TAC Tyr	GCT Ala	GGC Gly 280	TGC Cys	CGC Arg	GTG Val	GCG Ala	924
GTG Val 285	ACC Thr	TTC Phe	TTC Phe	CTC Leu 290	TAC Tyr	TTC Phe	CTG Leu	GCT Ala	ACC Thr 295	AAC Asn	TAC Tyr	TAC Tyr	TGG Trp	ATT Ile 300	CTG Leu	972
GTG Val	GAG Glu	GGG Gly	CTG Leu 305	TAC Tyr	TTG Leu	CAC His	AGC Ser	CTC Leu 310	ATC Ile	TTC Phe	ATG Met	GCC Ala	TTT Phe 315	TTC Phe	TCA Ser	1020
GAG Glu	AAG Lys 320	AAG Lys	TAC Tyr	CTG Leu	TGG Trp	GGC Gly	TTC Phe 325	ACC Thr	ATC Ile	TTT Phe	GGC Gly	TGG Trp 330	GGT Gly	CTA Leu	CCG Pro	1068
GCT Ala 335	GTC Val	TTC Phe	GTG Val	GCT Ala	GTG Val	TGG Trp 340	GTC Val	GGT Gly	GTC Val	AGA Arg	GCA Ala 345	ACC Thr	TTG Leu	GCC Ala	AAC Asn	1116
ACT Thr 350	GGG Gly	TGC Cys	TGG Trp	GAT Asp	CTG Leu 355	AGC Ser	TCC Ser	GGG Gly	CAC His	AAG Lys 360	AAG Lys	TGG Trp	ATC Ile	ATC Ile	CAG Gln 365	1164
GTG Val	CCC Pro	ATC Ile	CTG Leu	GCA Ala 370	TCT Ser	GTT Val	GTG Val	CTC Leu	AAC Asn 375	TTC Phe	ATC Ile	CTT Leu	TTT Phe	ATC Ile 380	AAC Asn	1212





Claims

1           1.     Isolated DNA comprising a DNA sequence encoding  
2     a cell receptor of a vertebrate animal, said receptor having  
3     an amino acid sequence with at least 30% identity to the  
4     amino acid sequence shown in FIG. 3.

1           2.     The isolated DNA of claim 1, wherein said DNA  
2     sequence encodes substantially all of the amino acid  
3     sequence shown in FIG. 1 (SEQ. ID NO. 1).

1           3.     The isolated DNA of claim 1, wherein said DNA  
2     sequence encodes substantially all of the amino acid  
3     sequence shown in FIG. 3 (SEQ. ID NO. 3).

1           4.     The isolated DNA of claim 1, said isolated DNA  
2     being (8A6), deposited with the ATCC and designated ATCC  
3     Accession No. 68570.

1           5.     The isolated DNA of claim 1, wherein said DNA  
2     sequence encodes substantially all of the amino acid  
3     sequence shown in Fig. 6 (SEQ. ID. NO. 4).

1           6.     The isolated DNA of claim 1, wherein said DNA  
2     sequence hybridizes to the DNA sequence shown in Fig. 1  
3     (SEQ. ID NO. 1).

1           7.     The isolated DNA of claim 1, wherein said DNA  
2     sequence hybridizes to the DNA sequence shown in Fig. 3  
3     (SEQ. ID NO. 3).

1           8.    The isolated DNA of claim 1, wherein said DNA  
2   sequence hybridizes to the DNA sequence shown in Fig. 6  
3   (SEQ. ID NO. 4).

1           9.    A purified preparation of a vector, said vector  
2   comprising a DNA sequence encoding a parathyroid hormone  
3   receptor.

1           10.   A cell containing the isolated DNA of claim 1.

1           11.   The cell of claim 10, wherein said cell is  
2   capable of expressing said cell receptor from said isolated  
3   DNA.

1           12.   An essentially homogenous population of cells,  
2   each of which comprises the isolated DNA of claim 1.

1           13.   Isolated DNA comprising a DNA sequence encoding  
2   a polypeptide capable of binding parathyroid hormone or  
3   parathyroid-hormone-related protein.

1           14.   A method for producing a polypeptide, said  
2   method comprising:

3                providing a cell comprising isolated DNA  
4   encoding a parathyroid hormone receptor or a fragment  
5   thereof; and

6                culturing said cell under conditions permitting  
7   expression of a polypeptide from said DNA.

1           15.   A single-stranded DNA comprising a portion of a  
2   parathyroid hormone receptor gene, said portion being at  
3   least 18 nucleotides long.

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1           16. The single-stranded DNA of claim 15, wherein  
2 said portion is less than all of said parathyroid hormone  
3 receptor gene.

1           17. The single-stranded DNA of claim 15, wherein  
2 said DNA is detectably labeled.

1           18. A single-stranded DNA comprising a portion of a  
2 parathyroid hormone receptor cDNA, said portion being at  
3 least 18 nucleotides long.

1           19. The single-stranded DNA of claim 18, wherein  
2 said DNA is antisense.

1           20. Parathyroid hormone receptor produced by  
2 expression of a recombinant DNA molecule encoding a  
3 parathyroid hormone receptor.

1           21. An essentially purified preparation of the  
2 parathyroid hormone receptor of claim 20.

1           22. An essentially purified preparation of the  
2 parathyroid receptor produced by the expression of the DNA  
3 of claim 5.

1           23. A polypeptide comprising at least six amino  
2 acids and less than the complete amino acid sequence of a  
3 parathyroid hormone receptor, said polypeptide capable of  
4 binding parathyroid hormone or parathyroid hormone-related  
5 protein.

1           24. The polypeptide of claim 23, wherein said  
2 parathyroid hormone receptor is a human parathyroid  
3 receptor.

1           25. The polypeptide of claim 23, wherein said  
2 fragment comprises  
3           (a) TNETREREVFDRLGMIYTVG,  
4           (b) YLYSGFTLDEAERLTEEEL,  
5           (c) VTFFLYFLATNYYWILVEG,  
6           (d) Y-RATLANTGCWDLSSGHKKWIIQVP,  
7           (e) PYTEYSGTLWQIQMHYEM,  
8           (f) DDVFTKEEQIFLLHRAQA,  
9           (g) FFRLHCTRNY,  
10          (h) EKKYLVGFTL,  
11          (i) VLATKLRETNAGRCDTROQYRKLLK, or  
12          (j) a fragment of (a) - (i) which is capable of  
13 binding parathyroid hormone or parathyroid hormone-related  
14 protein.

1           26. A therapeutic composition comprising, in a  
2 pharmaceutically-acceptable carrier, (a) a parathyroid  
3 hormone receptor or (b) a polypeptide comprising a fragment  
4 of said receptor.

1           27. An antibody capable of forming an immune  
2 complex with a parathyroid hormone receptor.

1           28. A therapeutic composition comprising the  
2 antibody of claim 27 and a pharmaceutically-acceptable  
3 carrier.

1           29. A method of reducing the level of calcium in  
2 the blood of a mammal, which method comprises administering

3 the therapeutic composition of claim 26 to said mammal in a  
4 dosage effective to inhibit activation by parathyroid  
5 hormone or parathyroid hormone-related protein of a  
6 parathyroid hormone receptor of said mammal.

1 30. A method of reducing the level of calcium in  
2 the blood of a mammal, which method comprises administering  
3 the therapeutic composition of claim 28 to said mammal in a  
4 dosage effective to inhibit activation by parathyroid  
5 hormone or parathyroid hormone-related protein of a  
6 parathyroid hormone receptor of said mammal.

1 31. A method for identifying a compound capable of  
2 competing with a parathyroid hormone for binding to a  
3 parathyroid hormone receptor, said method comprising:

4 (a) contacting the polypeptide of claim 23 with a  
5 parathyroid hormone, (i) in the presence or (ii) in the  
6 absence of a candidate compound; and

7 (b) comparing (i) the level of binding of said  
8 polypeptide to said parathyroid hormone in the presence of  
9 said candidate compound, with (ii) the level of binding of  
10 said polypeptide to said parathyroid hormone in the absence  
11 of said candidate compound; a lower level of binding in the  
12 presence of said candidate compound than in its absence  
13 indicating that said candidate compound is capable of  
14 competing with said parathyroid hormone for binding to said  
15 receptor.

1 32. A method for identifying a compound capable of  
2 competing with a parathyroid hormone-related protein for  
3 binding to a parathyroid hormone receptor, said method  
4 comprising:



5 (a) contacting the polypeptide of claim 23 with a  
6 parathyroid hormone-related protein, (i) in the presence or  
7 (ii) in the absence of a candidate compound; and

8 (b) comparing (i) the level of binding of said  
9 polypeptide to said parathyroid hormone-related protein in  
10 the presence of said candidate compound, with (ii) the level  
11 of binding of said polypeptide to said parathyroid hormone-  
12 related protein in the absence of said candidate compound; a  
13 lower level of binding in the presence of said candidate  
14 compound than in its absence indicating that said candidate  
15 compound is capable of competing with said parathyroid  
16 hormone-related protein for binding to said receptor.

1 33. A method for identifying a compound capable of  
2 competing with a parathyroid hormone for binding to a  
3 parathyroid hormone receptor, said method comprising:

4 (a) combining a parathyroid hormone with the cell  
5 of claim 11, (i) in the presence or (ii) in the absence of a  
6 candidate compound; and

7 (b) comparing (i) the level of binding of said  
8 receptor to said parathyroid hormone in the presence of said  
9 candidate compound, with (ii) the level of binding of said  
10 receptor to said parathyroid hormone in the absence of said  
11 candidate compound; a lower level of binding in the presence  
12 of said candidate compound than in its absence indicating  
13 that said candidate compound is capable of competing with  
14 said parathyroid hormone for binding to said receptor.

1 34. A compound capable of inhibiting the binding of  
2 parathyroid hormone or parathyroid hormone-related protein  
3 to a parathyroid receptor on the surface of a cell.

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1           35. A therapeutic composition comprising the  
2 compound of claim 34 and a pharmaceutically-acceptable  
3 carrier.

1           36. A method for identifying a DNA sequence  
2 homologous to a parathyroid hormone receptor-encoding DNA  
3 sequence, said method comprising:  
4           providing a genomic or cDNA library;  
5           contacting said library with the single-  
6 stranded DNA of claim 18, under conditions permitting  
7 hybridization between said single-stranded DNA and a  
8 homologous DNA sequence in said library; and  
9           identifying a clone from said library which  
10 hybridizes to said single-stranded DNA, said hybridization  
11 being indicative of the presence in said clone of a DNA  
12 sequence homologous to a parathyroid hormone receptor-  
13 encoding DNA sequence.

1           37. A transgenic non-human vertebrate animal  
2 bearing a transgene comprising a DNA sequence encoding  
3 parathyroid hormone receptor or a fragment thereof.

1           38. A diagnostic method comprising:  
2           (a) obtaining a first blood sample from an animal;  
3           (b) administering the composition of claim 35 to  
4 said animal;  
5           (c) obtaining a second blood sample from said  
6 animal subsequent to said administration of said  
7 composition; and  
8           (d) comparing the calcium level in said first blood  
9 sample with that in said second blood sample, a lower  
10 calcium level in said second blood sample being diagnostic  
11 for a parathyroid hormone-related condition.

1

Abstract

DNA encoding a parathyroid hormone receptor;  
production and isolation of recombinant and synthetic  
parathyroid hormone receptor polypeptides and fragments;  
antibodies to parathyroid hormone receptors and receptor  
fragments; methods for screening candidate compounds for  
antagonistic or agonistic effects on parathyroid hormone  
receptor action; and diagnostic and therapeutic methods of  
these compounds are disclosed.

APPL2880.BOS

FIG. 1.

TGGGCACAGC	CACCCTGTTG	GTAGTCCAGG	GGCCAGCCCA	CTGAGCTGGC	ATATCAGCTG	50
GTGGCCCCCGT	TGGACTCGGC	CCTAGGGAAC	GGCGGGCG	ATG GGA GCG CCC CGG ATC	115	
				Met Gly Ala Pro Arg Ile		
				1 5		
TCG CAC AGC CTT GCC TTG CTC CTC TGC TGC TCC GTG CTC AGC TCC GTC	163					
Ser His Ser Leu Ala Leu Leu Leu Cys Cys Ser Val Leu Ser Ser Val						
10 15 20						
TAC GCA CTG GTG GAT GCC GAT GAT GTC ATA ACG AAG GAG GAG CAG ATC	211					
Tyr Ala Leu Val Asp Ala Asp Asp Val Ile Thr Lys Glu Glu Gln Ile						
25 30 35						
ATT CTT CTG CGC AAT GCC CAG GCC CAG TGT GAG CAG CGC CTG AAA GAG	259					
Ile Leu Leu Arg Asn Ala Gln Ala Gln Cys Glu Gln Arg Leu Lys Glu						
40 45 50						
GTC CTC AGG GTC CCT GAA CTT GCT GAA TCT GCC AAA GAC TGG ATG TCA	307					
Val Leu Arg Val Pro Glu Leu Ala Glu Ser Ala Lys Asp Trp Met Ser						
55 60 65 70						
AGG TCT GCA AAG ACA AAG AAG GAG AAA CCT GCA GAA AAG CTT TAT CCC	355					
Arg Ser Ala Lys Thr Lys Lys Glu Lys Pro Ala Glu Lys Leu Tyr Pro						
75 80 85						
CAG GCA GAG GAG TCC AGG GAA GTT TCT GAC AGG AGC CGG CTG CAG GAT	403					
Gln Ala Glu Glu Ser Arg Glu Val Ser Asp Arg Ser Arg Leu Gln Asp						
90 95 100						
GGC TTC TGC CTA CCT GAG TGG AAC AAC ATT GTG TGC TGG CCT GCT GGA	451					
Gly Phe Cys Leu Pro Glu Trp Asp Asn Ile Val Cys Trp Pro Ala Gly						
105 110 115						
GTG CCC GGC AAG GTG GTG GCC GTG CCC TGC CCC GAC TAC TTC TAC GAC	499					
Val Pro Gly Lys Val Val Ala Val Pro Cys Pro Asp Tyr Phe Tyr Asp						
120 125 130						
TTC AAC CAC AAA GGC CGA GCC TAT CGG CGC TGT GAC AGC AAT GGC AGC	547					
Phe Asn His Lys Gly Arg Ala Tyr Arg Arg Cys Asp Ser Asn Gly Ser						
135 140 145 150						
TGG GAG CTG GTG CCT GGG AAC AAC CGG ACA TGG GCG AAT TAC AGC GAA	595					
Trp Glu Leu Val Pro Gly Asn Asn Arg Thr Trp Ala Asn Tyr Ser Glu						
155 160 165						
TGT GTC AAG TTT CTG ACC AAC GAG ACC CGG GAA CGG GAA GTC TTT GAT	643					
Cys Val Lys Phe Leu Thr Asn Glu Thr Arg Glu Arg Glu Val Phe Asp						
170 175 180						

FIG.

CGC	CTC	GGA	ATG	ATC	TAC	ACT	GTG	GGC	TAC	TCC	ATC	TCT	CTG	GGC	TCC	691
Arg	Leu	Gly	Met	Ile	Tyr	Thr	Val	Gly	Tyr	Ser	Ile	Ser	Leu	Gly	Ser	
		185					190					195				
CTC	ACT	GTG	GCT	GTG	CTG	ATT	CTG	GGT	TAC	TTT	AGG	AGG	TTA	CAT	TGC	739
Leu	Thr	Val	Ala	Val	Leu	Ile	Leu	Gly	Tyr	Phe	Arg	Arg	Leu	His	Cys	
	200					205					210					
ACC	CGA	AAC	TAC	ATT	CAC	ATG	CAT	CTC	TTC	GTG	TCC	TTT	ATG	CTC	CGG	787
Thr	Arg	Asn	Tyr	Ile	His	Met	His	Leu	Phe	Val	Ser	Phe	Met	Leu	Arg	
	215				220					225					230	
GCT	GTA	AGC	ATC	TTC	ATC	AAG	GAT	GCT	GTG	CTC	TAC	TCG	GGG	GTT	TCC	835
Ala	Val	Ser	Ile	Phe	Ile	Lys	Asp	Ala	Val	Leu	Tyr	Ser	Gly	Val	Ser	
				235					240					245		
ACA	GAT	GAA	ATC	GAG	CGC	ATC	ACC	GAG	GAG	GAG	CTG	AGG	GCC	TTC	ACA	883
Thr	Asp	Glu	Ile	Glu	Arg	Ile	Thr	Glu	Glu	Glu	Leu	Arg	Ala	Phe	Thr	
			250					255					260			
GAG	CCT	CCC	CCT	GCT	GAC	AAG	GGC	GGT	TTT	GTG	GGC	TGC	AGA	GTG	GCG	931
Glu	Pro	Pro	Pro	Ala	Asp	Lys	Ala	Gly	Phe	Val	Gly	Cys	Arg	Val	Ala	
		265					270					275				
GTA	ACC	GTC	TTC	CTT	TAC	TTC	CTG	ACC	ACC	AAC	TAC	TAC	TGG	ATC	CTG	979
Val	Thr	Val	Phe	Leu	Tyr	Phe	Leu	Thr	Thr	Asn	Tyr	Tyr	Trp	Ile	Leu	
	280					285					290					
GTG	GAA	GGC	CTC	TAC	CTT	CAC	AGC	CTC	ATC	TTC	ATG	GCT	TTT	TTC	TCT	1027
Val	Glu	Gly	Leu	Tyr	Leu	His	Ser	Leu	Ile	Phe	Met	Ala	Phe	Phe	Ser	
	295				300					305					310	
GAG	AAA	AAG	TAT	CTC	TGG	GGT	TTC	ACA	TTA	TTT	GGC	TGG	GGC	CTC	CCT	1075
Glu	Lys	Lys	Tyr	Leu	Trp	Gly	Phe	Thr	Leu	Phe	Gly	Trp	Gly	Leu	Pro	
				315					320					325		
ACC	ATC	TTT	CTC	GCT	GTG	TCG	TCG	CTC	GTG	AGG	GCT	ACA	CTG	GCC	AAC	1123
Ala	Val	Phe	Val	Ala	Val	Trp	Val	Thr	Val	Arg	Ala	Thr	Leu	Ala	Asn	
			330					335					340			
ACT	GAG	TGC	TGG	GAC	CTG	AGT	TCG	GGG	AAT	AAG	AAA	TGG	ATC	ATA	CAG	1171
Thr	Glu	Cys	Trp	Asp	Leu	Ser	Ser	Gly	Asn	Lys	Lys	Trp	Ile	Ile	Gln	
		345					350					355				
GTG	CCC	ATC	CTG	GCA	GCT	ATT	GTG	CTG	AAC	TTT	ATT	CTT	TTT	ATC	AAT	1219
Val	Pro	Ile	Leu	Ala	Ala	Ile	Val	Val	Asn	Phe	Ile	Leu	Phe	Ile	Asn	
	360					365					370					
ATA	ATC	AGA	GTC	CTG	GCT	ACT	AAA	CTC	GGG	GAG	ACC	AAT	GCA	GGG	AGA	1267
Ile	Ile	Arg	Val	Leu	Ala	Thr	Lys	Leu	Arg	Glu	Thr	Asn	Ala	Gly	Arg	
	375				380					385					390	

GAGCTT-TAGCTA

FIG. 1

TGT	GAC	ACG	AGG	CAA	CAG	TAT	AGA	AAG	CTG	CTG	AAG	TCC	ACG	CTA	GTC	1315
Cys	Asp	Thr	Arg	Gln	Gln	Tyr	Arg	Lys	Leu	Leu	Lys	Ser	Thr	Leu	Val	
				395					400					405		
CTC	ATG	CCG	CTA	TTT	GGG	GTG	CAC	TAC	ATC	GTC	TTC	ATG	GCC	ACG	CCG	1353
Leu	Met	Pro	Leu	Phe	Gly	Val	His	Tyr	Ile	Val	Phe	Met	Ala	Thr	Pro	
			410					415					420			
TAC	ACA	GAA	GTA	TCA	GGG	ATT	CTT	TGG	CAA	GTC	CAA	ATG	CAC	TAT	GAA	1411
Tyr	Thr	Glu	Val	Ser	Gly	Ile	Leu	Trp	Gln	Val	Gln	Met	His	Tyr	Glu	
		425					430					435				
ATG	CTC	TTC	AAT	TCA	TTC	CAG	GGA	TTT	TTC	GTT	GCC	ATT	ATA	TAC	TGT	1459
Met	Leu	Phe	Asn	Ser	Phe	Gln	Gly	Phe	Phe	Val	Ala	Ile	Ile	Tyr	Cys	
	440					445					450					
TTC	TGC	AAT	GGA	GAG	GTA	CAA	GCA	GAG	ATC	AAG	AAG	TCA	TGG	AGC	CGA	1507
Phe	Cys	Asn	Gly	Glu	Val	Gln	Ala	Glu	Ile	Lys	Lys	Ser	Trp	Ser	Arg	
455				460				465							470	
TGG	ACC	CTG	GCC	TTG	GAC	TTC	AAG	CGG	AAG	GCC	CGG	AGT	GGC	AGC	AGT	1555
Trp	Thr	Leu	Ala	Leu	Asp	Phe	Lys	Arg	Lys	Ala	Arg	Ser	Gly	Ser	Ser	
				475				480						485		
ACC	TAC	AGC	TAT	GGC	CCC	ATG	GTG	TCA	CAT	ACA	AGT	GTC	ACC	AAT	GTG	1603
Thr	Tyr	Ser	Tyr	Gly	Pro	Met	Val	Ser	His	Thr	Ser	Val	Thr	Asn	Val	
			490					495					500			
GGA	CCT	CGA	GGG	GGC	TGG	CCT	TGT	CCC	TCA	GCC	CTC	GAC	TAGCTCCTGG			1652
Gly	Pro	Arg	Gly	Gly	Trp	Pro	Cys	Pro	Ser	Ala	Leu	Asp				
	505					510						515				
GGCTGGAGCC	AGTGGCAATG	GCCATCACCA	GTTGCCTGGC	TATGTGAAGC	ATGGTTCCAT											1712
TTCTGAGAAC	TCATTGCCTT	CATCTGGCCC	AGAGCCTGGC	ACCAAAGATG	ACGGGTATCT											1771
CAATGGCTCT	GGACTTTATG	AGCCAAATGT	TGGGGAACAG	CCCCCTCCAC	TCCTGGAGGA											1832
GGAGAGAGAG	ACAGTCATGT	GACCCATATC														1862

Sequence 42505150

09 78666666 66666666 66666666 66666666 66666666 66666666 66666666 66666666 66666666 66666666

GTGCCCCCGT TGGACTCGGC CCTAGGGGAACT GGGGGCGG ATG GGA GCG CCC CGG ATC  
Met Gly Ala Pro Arg Ile  
1  
5  
115

[illegible]

211

ATT CTG CTG CCG AAT GCC CAG GCC CAG TGT GAG CAG CGC CTG AAA GAG  
 40 Ile Leu Leu Arg Asn Ala Gln Ala Gln Cys Gln Arg Leu Lys Gln  
 50  
 259

55 Val Leu Arg Val Pro Glu GAA GTT GGT GAA TCT GCC AAA GAC TGC ATG TCA  
55 Val Leu Arg Val Pro Glu Leu Ala Glu Ser Ala Lys Asp Trp Met Ser

70

355 TCT GCA AAG ACA AAG AAG GAG AAA CCT GCA GAA AAG CTT TAT CCC  
arg Ser Ala Lys Thr Lys Lys Gln Lys Pro Ala Gln Lys Leu Tyr Pro  
75 80 85

403 2071

451

TG	CCC	GCG	CAG	GTG	GTG	GCC	ACC	ACC	TGC	TGC	CCC	GAC	TAC	TTC	TAC	GAC
at	Pro	Gly	Lys	Val	Val	Ala	Leu	Ile	Phe	Arg	Pro	Asp	Tyr	Phe	Tyr	Asp
	120					125						130				

499

TC AAC CAC AAA GGC CGA GCC CAT GCG CGC TGT GAC AGC AAT GGC AGC  
 the Asn His Lys Gly Arg Ala Tyr Arg Arg Cys Asp Ser Asn Gly Ser  
 35 140 145 150

595

GT GTC AAG TTT CTG ACC AAC GAG ACC CCG GAA CCG GAA CCG GTC TTT GAT  
YS Val Lys Phe Leu Thr Asn Gln Thr Arg Gln Arg Gln Val Phe Asp  
170  
180



691	CGC CTC GGA ATG ATC TAC ACT GTG GGC TAC TCC ATC TCT CTC GGC TCC	Arg Leu Gly Met Ile Tyr Thr Val Gly Tyr Ser Ile Ser Leu Gly Ser	185
	CTC ACT GTG GCT GTG CTG ATT CTG GGT TAC TTT AGG AGG TTA CAT TGC	Leu Thr Val Ala Val Leu Ile Leu Gly Tyr Phe Arg Arg Leu His Cys	200
787	ACC CGA AAC TAC ATT CAC ATG CAT CTC TTC GTG TCC TTT ATG CTC CGG	Thr Arg Asn Tyr Ile His Met His Leu Phe Val Ser Phe Met Leu Arg	215
	GCT GTA AGC ATC TTC ATC AAG GAT GCT GTG CTC TAC TCG GGC GTT TCC	Ala Val Ser Ile Phe Ile Lys Asp Ala Val Leu Tyr Ser Gly Val Ser	235
883	ACA GAT GAA ATC GAG CGC ATC ACC GAG GAG CTC AGG GCC TTC ACA	Thr Asp Glu Ile Glu Arg Ile Thr Glu Glu Glu Leu Arg Ala Phe Thr	250
931	GAG CGT CCC CGT GCT GAC AAG GCG GGT TTT GTG GGC TGC AGA GTG GCG	Glu Pro Pro Pro Ala Asp Lys Ala Gly Phe Val Gly Cys Arg Val Ala	275
979	GTA ACC GTC TTC CTT TAC TTC CTC ACC ACC AAC TAC TAC TCG ATC CTC	Val Thr Val Phe Leu Tyr Phe Leu Thr Thr Asn Tyr Tyr Trp Ile Leu	280
1027	GTG GAA GGC CTC TAC CTT CAC AGC CTC ATC TTC ATG GCT TTT TTC TCT	Val Glu Gly Leu Tyr Leu His Ser Leu Ile Phe Met Ala Phe Phe Ser	310
1075	GAG AAA AAG TAT CTC TCG GGT TTC ACA TTA TTT GGC TCG GGC CTC CCT	Glu Lys Lys Tyr Leu Trp Gly Phe Thr Leu Phe Gly Trp Gly Leu Pro	325
1123	GCC GTG TTT GTG GCT GTG TGG GTG ACC GTG AGG GGT ACA CTC GCC AAC	Ala Val Phe Val Ala Val Trp Val Thr Val Arg Ala Thr Leu Ala Asn	340
1171	ACT GAG TGC TGG GAC CTC AGT TCG AGT TCG GGC AAT AAG AAA TGG ATC CAG	Thr Glu Cys Trp Asp Leu Ser Ser Gly Asn Lys Lys Trp Ile Ile Glu	355
1219	GTG CCC ATC CTC GCA GCT ATT GTG GTG AAC TTT ATT CTT TTT ATC AAT	Val Pro Ile Leu Ala Ala Ile Val Val Asn Phe Ile Leu Phe Ile Asn	370
1267	ATA ATC AGA GTC CTC GCT ACT AAA CTC CGG GAG ACC AAT GCA GGG AGA	Ile Ile Arg Val Leu Ala Thr Lys Leu Arg Glu Thr Asn Ala Gly Arg	385
		Ile Ile Arg Val Leu Ala Thr Lys Leu Arg Glu Thr Asn Ala Gly Arg	390

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TGT	GAC	ACG	AGG	CAA	CAG	TAT	AGA	AAG	CTG	CTG	AAG	TCC	ACG	CTA	GTC	1315
Cys	Asp	Thr	Arg	Gln	Gln	Tyr	Arg	Lys	Leu	Leu	Lys	Ser	Thr	Leu	Val	
				395					400					405		
CTC	ATG	CCG	CTA	TTT	GGG	GTG	CAC	TAC	ATC	GTC	TTC	ATG	GCC	ACG	CCG	1363
Leu	Met	Pro	Leu	Phe	Gly	Val	His	Tyr	Ile	Val	Phe	Met	Ala	Thr	Pro	
			410					415					420			
TAC	ACA	GAA	GTA	TCA	GGG	ATT	CTT	TGG	CAA	GTC	CAA	ATG	CAC	TAT	GAA	1411
Tyr	Thr	Glu	Val	Ser	Gly	Ile	Leu	Trp	Gln	Val	Gln	Met	His	Tyr	Glu	
		425					430					435				
ATG	CTC	TTC	AAT	TCA	TTC	CAG	GGA	TTT	TTC	GTT	GCC	ATT	ATA	TAC	TGT	1459
Met	Leu	Phe	Asn	Ser	Phe	Gln	Gly	Phe	Phe	Val	Ala	Ile	Ile	Tyr	Cys	
	440					445					450					
TTC	TGC	AAT	GGA	GAG	GTA	CAA	GCA	GAG	ATC	AAG	AAG	TCA	TGG	AGC	CGA	1507
Phe	Cys	Asn	Gly	Glu	Val	Gln	Ala	Glu	Ile	Lys	Lys	Ser	Trp	Ser	Arg	
455				460				465							470	
TGG	ACC	CTG	GCC	TTG	GAC	TTC	AAG	CGG	AAG	GCC	CGG	AGT	GGC	AGC	AGT	1555
Trp	Thr	Leu	Ala	Leu	Asp	Phe	Lys	Arg	Lys	Ala	Arg	Ser	Gly	Ser	Ser	
			475					480					485			
ACC	TAC	AGC	TAT	GGC	CCC	ATG	GTG	TCA	CAT	ACA	AGT	GTC	ACC	AAT	GTG	1603
Thr	Tyr	Ser	Tyr	Gly	Pro	Met	Val	Ser	His	Thr	Ser	Val	Thr	Asn	Val	
			490					495				500				
GGA	CCT	CGA	GGG	GGG	CTG	GCC	TTG	TCC	CTC	AGC	CCT	CGA	CTA	GCT	CCT	1651
Gly	Pro	Arg	Gly	Gly	Leu	Ala	Leu	Ser	Leu	Ser	Pro	Arg	Leu	Ala	Pro	
		505					510					515				
GGG	GCT	GGA	GCC	AGT	GCC	AAT	GGC	CAT	CAC	CAG	TTG	CCT	GGC	TAT	GTG	1699
Gly	Ala	Gly	Ala	Ser	Ala	Asn	Gly	His	His	Gln	Leu	Pro	Gly	Tyr	Val	
	520					525					530					
AAG	CAT	GGT	TCC	ATT	TCT	GAG	AAC	TCA	TTG	CCT	TCA	TCT	GGC	CCA	GAG	1747
Lys	His	Gly	Ser	Ile	Ser	Glu	Asn	Ser	Leu	Pro	Ser	Ser	Gly	Pro	Glu	
535					540					545					550	
CCT	GGC	ACC	AAA	GAT	GAC	GGG	TAT	CTC	AAT	GGC	TCT	GGA	CTT	TAT	GAG	1795
Pro	Gly	Thr	Lys	Asp	Asp	Gly	Tyr	Leu	Asn	Gly	Ser	Gly	Leu	Tyr	Glu	
				555				560					565			
CCA	ATG	GTT	GGG	GAA	CAG	CCC	CCT	CCA	CTC	CTG	GAG	GAG	GAG	AGA	GAG	1843
Pro	Met	Val	Gly	Glu	Gln	Pro	Pro	Pro	Leu	Leu	Glu	Glu	Glu	Arg	Glu	
			570					575					580			
ACA	GTC	ATG	TGACCCATAT C													1863
Thr	Val	Met														
		585														

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GGCGGGGGCC	GCGGCGGCGA	GCTCGGAGGC	CGGCGGCGGC	TGCCCCGAGG	GACGCGGCCC	60										
TAGGCGGTGG	CG	ATG	GGG	GCC	GCC	CGG	ATC	GCA	CCC	AGC	CTG	GCG	CTC	108		
	Met	Gly	Ala	Ala	Arg	Ile	Ala	Pro	Ser	Leu	Ala	Leu				
	1					5					10					
CTA	CTC	TGC	TGC	CCA	GTG	CTC	AGC	TCC	GCA	TAT	GCG	CTG	GTG	GAT	GCG	156
Leu	Leu	Cys	Cys	Pro	Val	Leu	Ser	Ser	Ala	Tyr	Ala	Leu	Val	Asp	Ala	
		15					20					25				
GAC	GAT	GTC	TTT	ACC	AAA	GAG	GAA	CAG	ATT	TTC	CTG	CTG	CAC	CGT	GCC	204
Asp	Asp	Val	Phe	Thr	Lys	Glu	Glu	Gln	Ile	Phe	Leu	Leu	His	Arg	Ala	
	30					35					40					
CAG	GCG	CAA	TGT	GAC	AAG	CTG	CTC	AAG	GAA	GTT	CTG	CAC	ACA	GCA	GCC	252
Gln	Ala	Gln	Cys	Asp	Lys	Leu	Leu	Lys	Glu	Val	Leu	His	Thr	Ala	Ala	
	45				50				55						60	
AAC	ATA	ATG	GAG	TCA	GAC	AAG	GGC	TGG	ACA	CCA	GCA	TCT	ACG	TCA	GGG	300
Asn	Ile	Met	Glu	Ser	Asp	Lys	Gly	Trp	Thr	Pro	Ala	Ser	Thr	Ser	Gly	
				65				70					75			
AAG	CCC	AGG	AAA	GAG	AAG	GCA	TCG	GGA	AAG	TTC	TAC	CCT	GAG	TCT	AAA	348
Lys	Pro	Arg	Lys	Glu	Lys	Ala	Ser	Gly	Lys	Phe	Tyr	Pro	Glu	Ser	Lys	
			80					85					90			
GAG	AAC	AAG	GAC	GTG	CCC	ACC	GGC	AGC	AGG	CGC	AGA	GGG	CGT	CCC	TGT	396
Glu	Asn	Lys	Asp	Val	Pro	Thr	Gly	Ser	Arg	Arg	Arg	Gly	Arg	Pro	Cys	
		95					100					105				
CTG	CCC	GAG	TGG	GAC	AAC	ATC	GTT	TGC	TGG	CCA	TTA	GGG	GCA	CCA	GGT	444
Leu	Pro	Glu	Trp	Asp	Asn	Ile	Val	Cys	Trp	Pro	Leu	Gly	Ala	Pro	Gly	
	110					115					120					
GAA	GTG	GTG	GCA	GTA	CCT	TGT	CCC	GAT	TAC	ATT	TAT	GAC	TTC	AAT	CAC	492
Glu	Val	Val	Ala	Val	Pro	Cys	Pro	Asp	Tyr	Ile	Tyr	Asp	Phe	Asn	His	
	125				130					135					140	
AAA	GGC	CAT	GCC	TAC	AGA	CGC	TGT	GAC	CGC	AAT	GGC	AGC	TGG	GAG	GTG	540
Lys	Gly	His	Ala	Tyr	Arg	Arg	Cys	Asp	Arg	Asn	Gly	Ser	Trp	Glu	Val	
				145				150					155			
GTT	CCA	GGG	CAC	AAC	CGG	ACG	TGG	GCC	AAC	TAC	AGC	GAG	TGC	CTC	AAG	588
Val	Pro	Gly	His	Asn	Arg	Thr	Trp	Ala	Asn	Tyr	Ser	Glu	Cys	Leu	Lys	
			160					165					170			
TTC	ATG	ACC	AAT	GAG	ACG	CGG	GAA	CGG	GAG	GTA	TTT	GAC	CGC	CTA	GGC	636
Phe	Met	Thr	Asn	Glu	Thr	Arg	Glu	Arg	Glu	Val	Phe	Asp	Arg	Leu	Gly	
		175					180					185				
ATG	ATC	TAC	ACC	GTG	GGA	TAC	TCC	ATG	TCT	CTC	GCC	TCC	CTC	ACG	GTG	684
Met	Ile	Tyr	Thr	Val	Gly	Tyr	Ser	Met	Ser	Leu	Ala	Ser	Leu	Thr	Val	
	190					195					200					

Sequence = 4366T60

FIG. 3

GCT Ala 205	GTG Val	CTC Leu	ATC Ile	CTG Leu	GCC Ala 210	TAT Tyr	TTT Phe	AGG Arg	CGG Arg	CTG Leu 215	CAC His	TGC Cys	ACG Thr	CGC Arg	AAC Asn 220	732
TAC Tyr	ATC Ile	CAC His	ATG Met	CAC His 225	ATG Met	TTC Phe	CTG Leu	TCG Ser	TTT Phe 230	ATG Met	CTG Leu	CGC Arg	GCC Ala	GCG Ala 235	AGC Ser	780
ATC Ile	TTC Phe	GTG Val	AAG Lys 240	GAC Asp	GCT Ala	GTG Val	CTC Leu	TAC Tyr 245	TCT Ser	GGC Gly	TTC Phe	ACG Thr	CTG Leu 250	GAT Asp	GAG Glu	828
GCC Ala	GAG Glu	CGC Arg 255	CTC Leu	ACA Thr	GAG Glu	GAA Glu	GAG Glu 260	TTG Leu	CAC His	ATC Ile	ATC Ile	GCG Ala 265	CAG Gln	GTG Val	CCA Pro	876
CCT Pro 270	CCG Pro	CCG Pro	GCC Ala	GCT Ala	GCC Ala	GCC Ala 275	GTA Val	GGC Gly	TAC Tyr	GCT Ala	GGC Gly 280	TGC Cys	CGC Arg	GTG Val	GCG Ala	924
GTG Val 285	ACC Thr	TTC Phe	TTC Phe	CTC Leu 290	TAC Tyr	TTC Phe	CTG Leu	GCT Ala	ACC Thr 295	AAC Asn	TAC Tyr	TAC Tyr	TGG Trp	ATT Ile 300	CTG Leu	972
GTG Val	GAG Glu	GGG Gly	CTG Leu 305	TAC Tyr	TTG Leu	CAC His	AGC Ser	CTC Leu 310	ATC Ile	TTC Phe	ATG Met	GCC Ala	TTT Phe 315	TTC Phe	TCA Ser	1020
GAG Glu	AAG Lys	AAG Lys 320	TAC Tyr	CTG Leu	TGG Trp	GGC Gly	TTC Phe 325	ACC Thr	ATC Ile	TTT Phe	GGC Gly	TGG Trp 330	GGT Gly	CTA Leu	CCG Pro	1068
GCT Ala 335	GTC Val	TTC Phe	GTC Val	GCT Ala	GTG Val	TGG Trp 340	GTC Val	GCT Val 345	GTC Val	AGA Arg	GCA Ala	ACC Thr	TTG Leu	GCC Ala	AAC Asn	1116
ACT Thr 350	GGG Gly	TGC Cys	TGC Trp	GAT Asp	CTG Leu 355	AGC Ser	TCC Ser	TCC Ser 360	CAC His	AAG Lys	AAG Lys	TGG Trp	ATC Ile	ATC Ile	CAG Gln 365	1164
GTG Val	CCC Pro	ATC Ile	CTG Leu	GCA Ala 370	TCT Ser	GTT Val	GTG Val	CTC Leu 375	AAC Asn	TTC Phe	ATC Ile	CTT Leu	TTT Phe 380	ATC Ile	AAC Asn	1212
ATC Ile	ATC Ile	CGG Arg 385	GTG Val	CTT Leu	GCC Ala	ACT Thr	AAG Lys	CTT Leu 390	CGG Arg	GAG Glu	ACC Thr	AAT Asn	GCG Ala 395	GGC Gly	CGG Arg	1260
TGT Cys	GAC Asp	ACC Thr 400	AGG Arg	CAG Gln	CAG Gln	TAC Tyr	CGG Arg 405	AAG Lys	CTG Leu	CTC Leu	AGG Arg	TCC Ser 410	ACG Thr	TTG Leu	GTG Val	1308

3045677  
 4865763



Gap Weight:	3.000	Average Match:	0.540
Length Weight:	0.100	Average Mismatch:	-0.396
Quality:	712.2	Lengths:	695
Ratio:	1.215	Gaps:	5
Percent Similarity:	87.113	Percent Identity:	77.835

Fig. 5

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R15 MGAARIAPSL ALLLCCPVLS SAYALVDADD VFTKEEQIFL LRAQAQCDE 50
OkO MGAPRISHSL ALLLCCSVLS SVYALVDADD VITKEEQIIL LRNAQAQCEQ 50
Okh MGAPRISHSL ALLLCCSVLS SVYALVDADD VITKEEQIIL LRNAQAQCEQ 50
----- A -----

R15 LLKEVLHTAA NIMESDKGWT PASTSGKPRK EKASGKPYFE SKENKDVPTG 100
OkO RLKEVLR.VP ELAESAKDW. .MSRSAKTRK EKPAEKLYPQ AEESREVS DR 97
Okh RLKEVLR.VP ELAESAKDW. .MSRSAKTRK EKPAEKLYPQ AEESREVS DR 97

R15 SRRRGFCPL EWDNIVCWPL GAPGEVVAVP CPDYIYDFNH KGHAYRRCDR 150
OkO SRLQDGFCLP EWDNIVCWPA GVP GKVVAVP CPDYFYDFNH KGRAYRRCD S 147
Okh SRLQDGFCLP EWDNIVCWPA GVP GKVVAVP CPDYFYDFNH KGRAYRRCD S 147
----- B -----
N N N N
R15 NGSWEVPGH NRTWANYSEC LKFMTNETRE REVFDRLGMI YTVGYSMSLA 200
OkO NGSWELVPGN NRTWANYSEC VKFLTNETRE REVFDRLGMI YTVGYISISLG 197
Okh NGSWELVPGN NRTWANYSEC VKFLTNETRE REVFDRLGMI YTVGYISISLG 197
-----

R15 SLTVAVLILA YFRRLHCTRN YIHMHMFLSF MLRAASIFVK DAVLYSGFTL 250
OkO SLTVAVLILG YFRRLHCTRN YIHMHMFLVSF MLRAVSIFIK DAVLYSGVST 247
Okh SLTVAVLILG YFRRLHCTRN YIHMHMFLVSF MLRAVSIFIK DAVLYSGVST 247
-- C -----

R15 DEAEERLTEE LHIIAQVPPP PAAAAGVYAG CRVAVTFPLY FLATNYWIL 300
OkO DEIERITEEE LRAFTE...P PPADKAGFVG CRVAVTVPLY FLTTNYWIL 294
Okh DEIERITEEE LRAFTE...P PPADKAGFVG CRVAVTVPLY FLTTNYWIL 294
----- E -----

R15 VEGLYLHSLI FMAFFSEKKY LWGFTLFGWG LPAVTVAVWV GVRATLANTG 350
OkO VEGLYLHSLI FMAFFSEKKY LWGFTLFGWG LPAVTVAVWV TVRATLANTE 344
Okh VEGLYLHSLI FMAFFSEKKY LWGFTLFGWG LPAVTVAVWV TVRATLANTE 344
-- F ----- G -----

R15 CWDLSSGHRK WIIQVPILAS VVLNPFILFIN IIRVLATKLR ETNAGRC DTR 400
OkO CWDLSSGNRK WIIQVPILAA IVVNPFILFIN IIRVLATKLR ETNAGRC DTR 394
Okh CWDLSSGNRK WIIQVPILAA IVVNPFILFIN IIRVLATKLR ETNAGRC DTR 394
----- H -----

R15 QQYRKLLRST LVLVPLFGVH YTVFMALPYT EVSGTLWQIQ MEYENLFNSF 450
OkO QQYRKLLRST LVLMLPLFGVH YIVFMATPYT EVSGILWQVQ MEYENLFNSF 444
Okh QQYRKLLRST LVLMLPLFGVH YIVFMATPYT EVSGILWQVQ MEYENLFNSF 444
----- I -----

R15 QGFFVAVIYC FCNGEVQAEI RKSWSRWTLA LDFKRKARSG SSSYSYGPMV 500
OkO QGFFVAVIYC FCNGEVQAEI KKSWSRWTLA LDFKRKARSG SSTYSYGPMV 494
Okh QGFFVAVIYC FCNGEVQAEI KKSWSRWTLA LDFKRKARSG SSTYSYGPMV 494
-- J -----

R15 SHTSVTNVGP RAGLSLPLSP RLFP...ATT NGHSQLPGEA KPGAPATETE 547
OkO SHTSVTNVGP RGGLALSLSF RLAPGAGASA NGHSQLPGYV KHGSISENSL 544
Okh SHTSVTNVGP RGG..... . . . . .NFCPSA LD 515

R15 TLPVTMAVPR DDGFLNGSCS GLDEEASGSA RPPPLLQEGW ETVM 591
OkO PSSGPEPGTK DDGYLNG..S GLYEPHVG.E QPPPLLZEER ETVM 585

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• With

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0	00000000	00000001	00000010	00000011	00000100	00000101	00000110	00000111	00001000	00001001	00001010	00001011	00001100	00001101	00001110	00001111	00010000	00010001	00010010	00010011	00010100	00010101	00010110	00010111	00011000	00011001	00011010	00011011	00011100	00011101	00011110	00011111	00100000	00100001	00100010	00100011	00100100	00100101	00100110	00100111	00101000	00101001	00101010	00101011	00101100	00101101	00101110	00101111	00110000	00110001	00110010	00110011	00110100	00110101	00110110	00110111	00111000	00111001	00111010	00111011	00111100	00111101	00111110	00111111	01000000	01000001	01000010	01000011	01000100	01000101	01000110	01000111	01001000	01001001	01001010	01001011	01001100	01001101	01001110	01001111	01010000	01010001	01010010	01010011	01010100	01010101	01010110	01010111	01011000	01011001	01011010	01011011	01011100	01011101	01011110	01011111	01100000	01100001	01100010	01100011	01100100	01100101	01100110	01100111	01101000	01101001	01101010	01101011	01101100	01101101	01101110	01101111	01110000	01110001	01110010	01110011	01110100	01110101	01110110	01110111	01111000	01111001	01111010	01111011	01111100	01111101	01111110	01111111	10000000	10000001	10000010	10000011	10000100	10000101	10000110	10000111	10001000	10001001	10001010	10001011	10001100	10001101	10001110	10001111	10010000	10010001	10010010	10010011	10010100	10010101	10010110	10010111	10011000	10011001	10011010	10011011	10011100	10011101	10011110	10011111	10100000	10100001	10100010	10100011	10100100	10100101	10100110	10100111	10101000	10101001	10101010	10101011	10101100	10101101	10101110	10101111	10110000	10110001	10110010	10110011	10110100	10110101	10110110	10110111	10111000	10111001	10111010	10111011	10111100	10111101	10111110	10111111	11000000	11000001	11000010	11000011	11000100	11000101	11000110	11000111	11001000	11001001	11001010	11001011	11001100	11001101	11001110	11001111	11010000	11010001	11010010	11010011	11010100	11010101	11010110	11010111	11011000	11011001	11011010	11011011	11011100	11011101	11011110	11011111	11100000	11100001	11100010	11100011	11100100	11100101	11100110	11100111	11101000	11101001	11101010	11101011	11101100	11101101	11101110	11101111	11110000	11110001	11110010	11110011	11110100	11110101	11110110	11110111	11111000	11111001	11111010	11111011	11111100	11111101	11111110	11111111



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[illegible]

1990-1991		1991-1992		1992-1993		1993-1994		1994-1995		1995-1996		1996-1997		1997-1998		1998-1999		1999-2000		2000-2001		2001-2002		2002-2003		2003-2004		2004-2005		2005-2006		2006-2007		2007-2008		2008-2009		2009-2010		2010-2011		2011-2012		2012-2013		2013-2014		2014-2015		2015-2016		2016-2017		2017-2018		2018-2019		2019-2020		2020-2021		2021-2022		2022-2023		2023-2024		2024-2025		2025-2026		2026-2027		2027-2028		2028-2029		2029-2030		2030-2031		2031-2032		2032-2033		2033-2034		2034-2035		2035-2036		2036-2037		2037-2038		2038-2039		2039-2040		2040-2041		2041-2042		2042-2043		2043-2044		2044-2045		2045-2046		2046-2047		2047-2048		2048-2049		2049-2050		2050-2051		2051-2052		2052-2053		2053-2054		2054-2055		2055-2056		2056-2057		2057-2058		2058-2059		2059-2060		2060-2061		2061-2062		2062-2063		2063-2064		2064-2065		2065-2066		2066-2067		2067-2068		2068-2069		2069-2070		2070-2071		2071-2072		2072-2073		2073-2074		2074-2075		2075-2076		2076-2077		2077-2078		2078-2079		2079-2080		2080-2081		2081-2082		2082-2083		2083-2084		2084-2085		2085-2086		2086-2087		2087-2088		2088-2089		2089-2090		2090-2091		2091-2092		2092-2093		2093-2094		2094-2095		2095-2096		2096-2097		2097-2098		2098-2099		2099-2100		2100-2101		2101-2102		2102-2103		2103-2104		2104-2105		2105-2106		2106-2107		2107-2108		2108-2109		2109-2110		2110-2111		2111-2112		2112-2113		2113-2114		2114-2115		2115-2116		2116-2117		2117-2118		2118-2119		2119-2120		2120-2121		2121-2122		2122-2123		2123-2124		2124-2125		2125-2126		2126-2127		2127-2128		2128-2129		2129-2130		2130-2131		2131-2132		2132-2133		2133-2134		2134-2135		2135-2136		2136-2137		2137-2138		2138-2139		2139-2140		2140-2141		2141-2142		2142-2143		2143-2144		2144-2145		2145-2146		2146-2147		2147-2148		2148-2149		2149-2150		2150-2151		2151-2152		2152-2153		2153-2154		2154-2155		2155-2156		2156-2157		2157-2158		2158-2159		2159-2160		2160-2161		2161-2162		2162-2163		2163-2164		2164-2165		2165-2166		2166-2167		2167-2168		2168-2169		2169-2170		2170-2171		2171-2172		2172-2173		2173-2174		2174-2175		2175-2176		2176-2177		2177-2178		2178-2179		2179-2180		2180-2181		2181-2182		2182-2183		2183-2184		2184-2185		2185-2186		2186-2187		2187-2188		2188-2189		2189-2190		2190-2191		2191-2192		2192-2193		2193-2194		2194-2195		2195-2196		2196-2197		2197-2198		2198-2199		2199-2200		2200-2201		2201-2202		2202-2203		2203-2204		2204-2205		2205-2206		2206-2207		2207-2208		2208-2209		2209-2210		2210-2211		2211-2212		2212-2213		2213-2214		2214-2215		2215-2216		2216-2217	
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[illegible]







FIG. 9

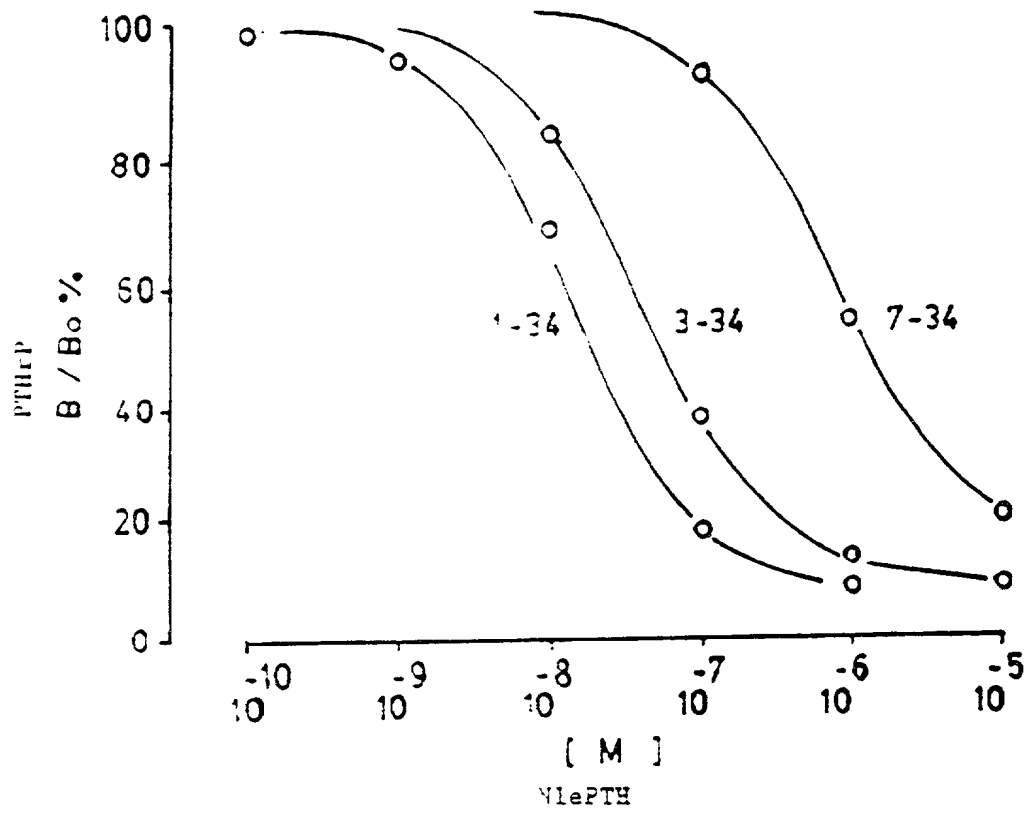


FIG. 10

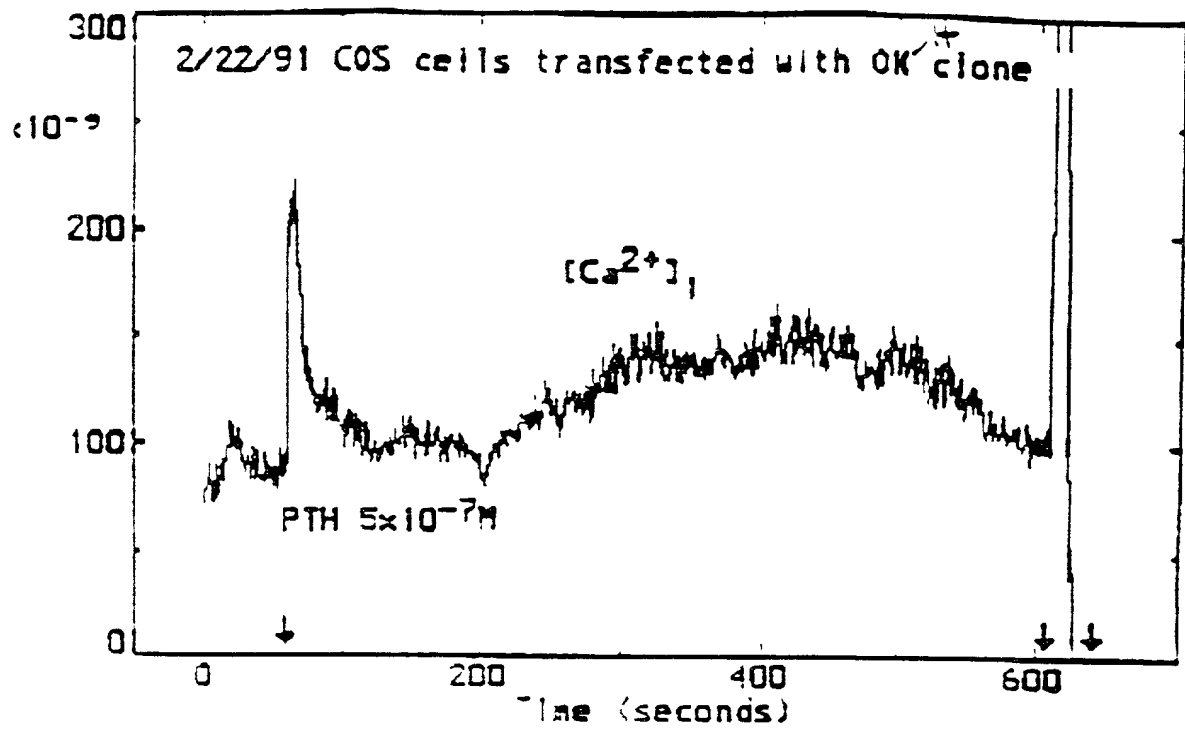


Fig. 11

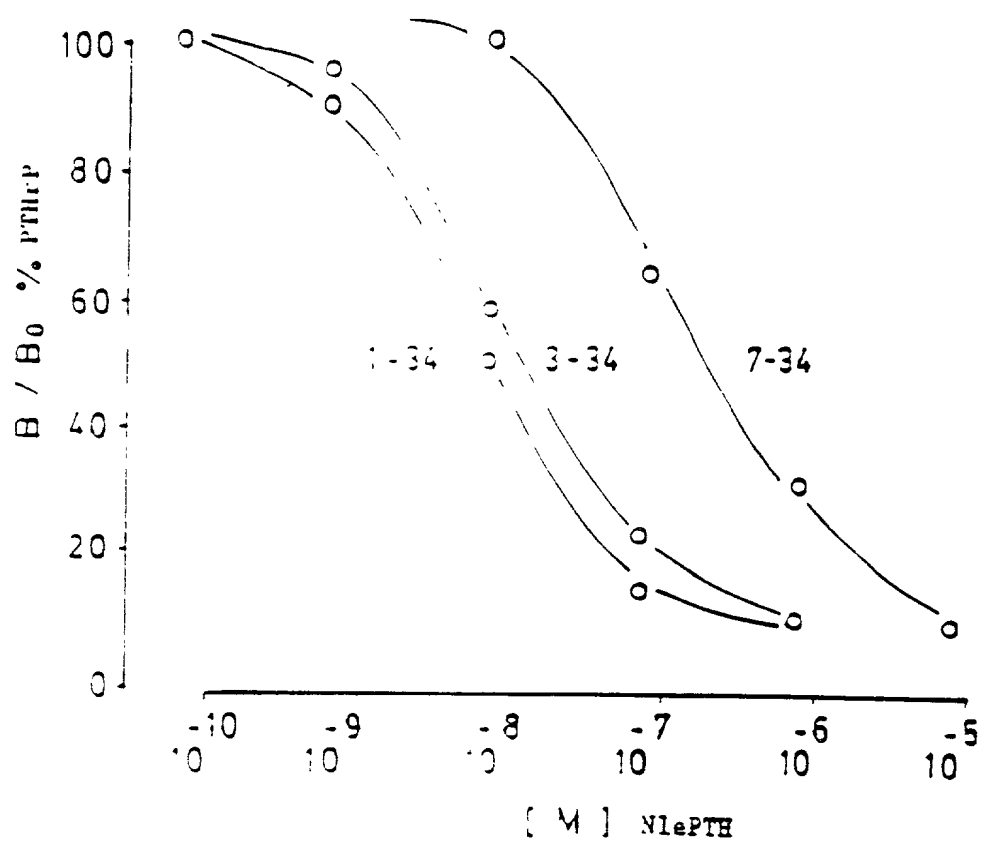
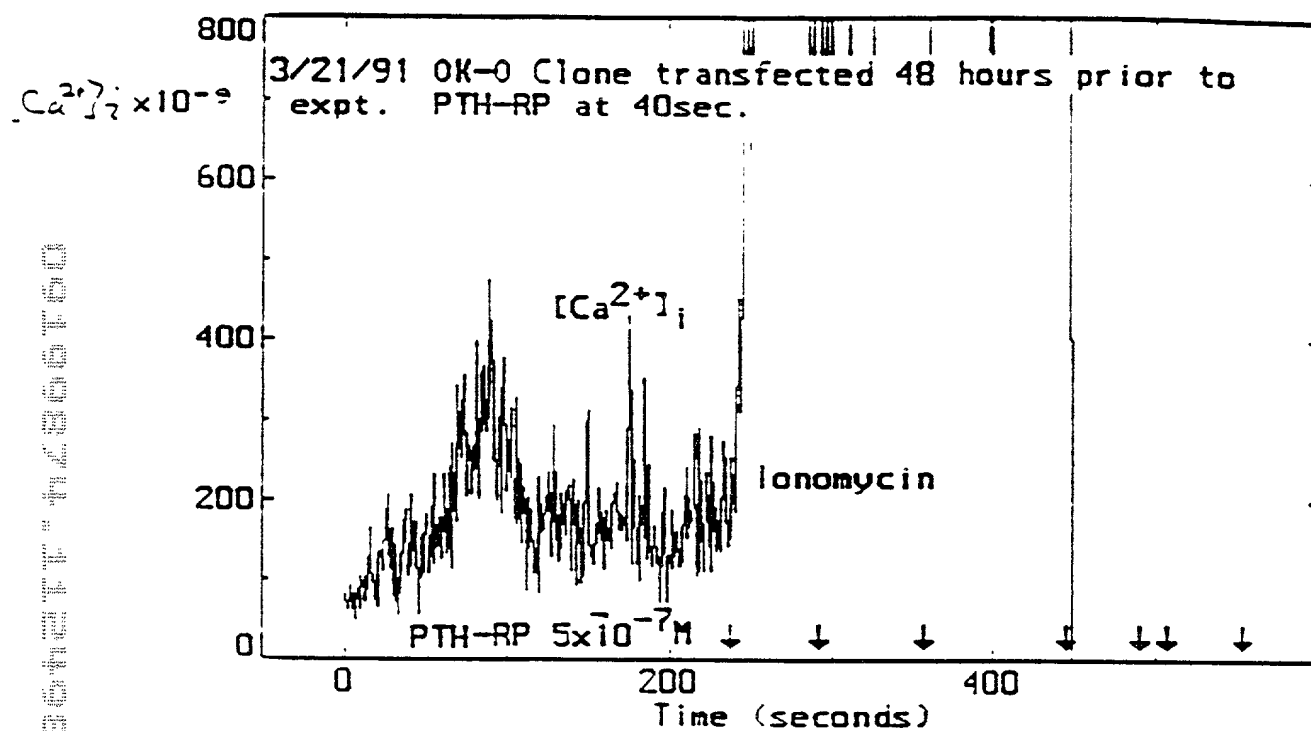




FIG.12



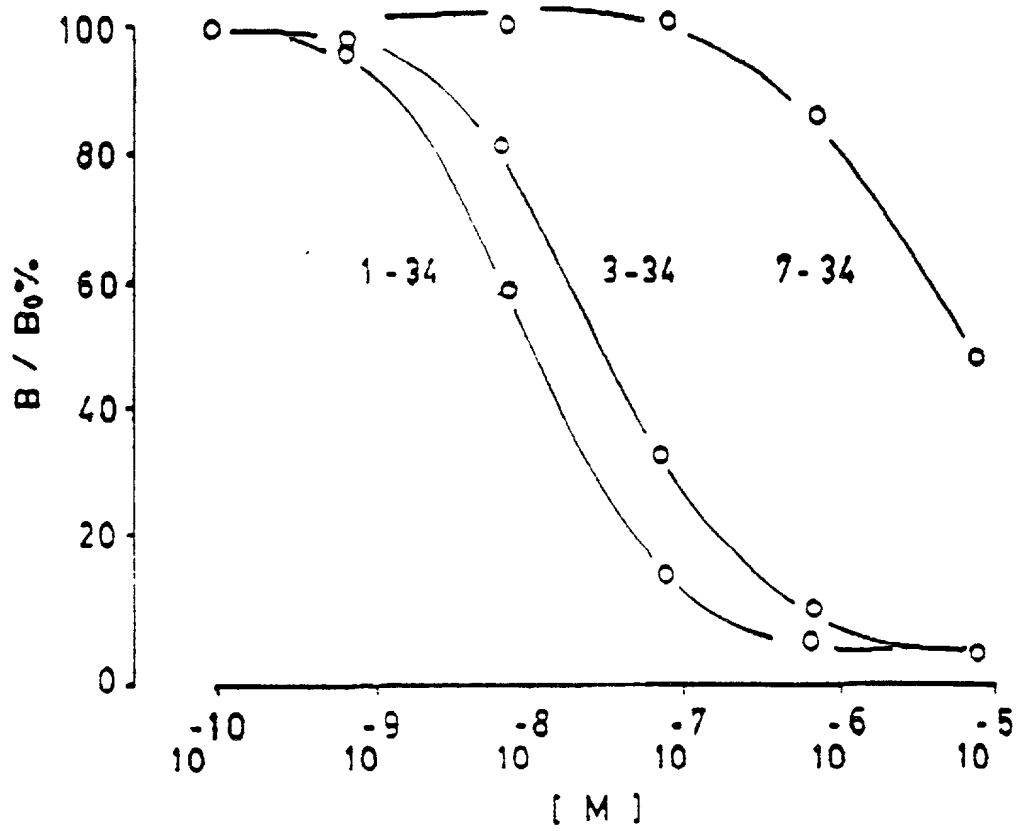


FIG. 13

FIG. 14

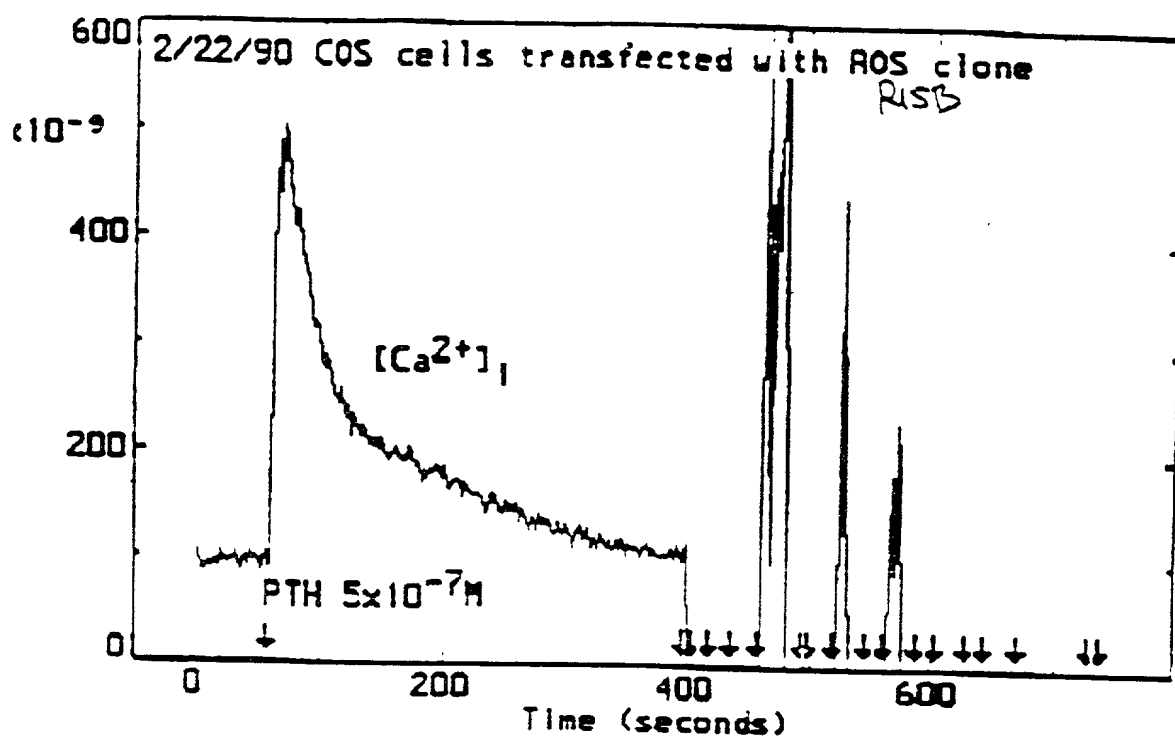


FIG. 15

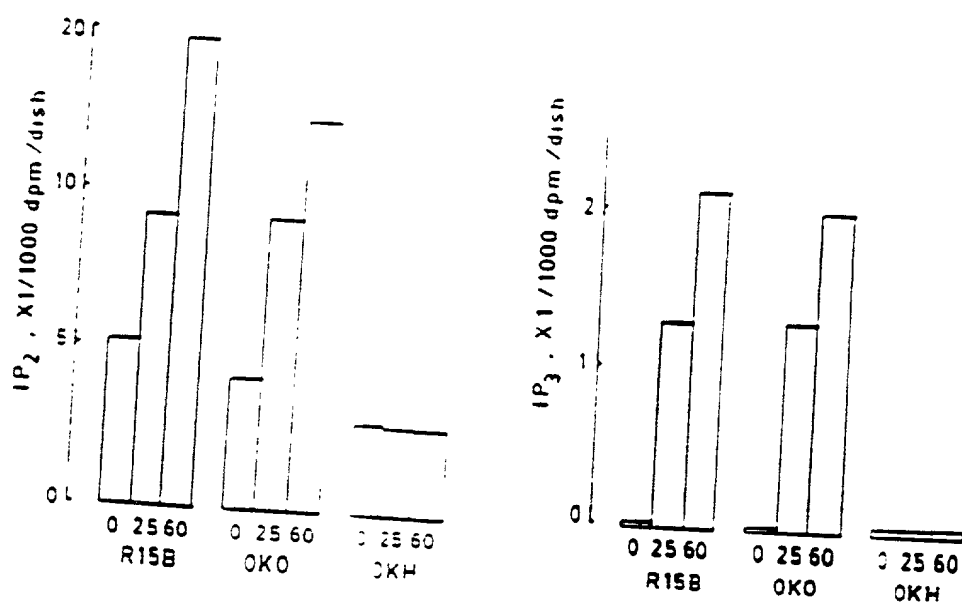


FIG. 16

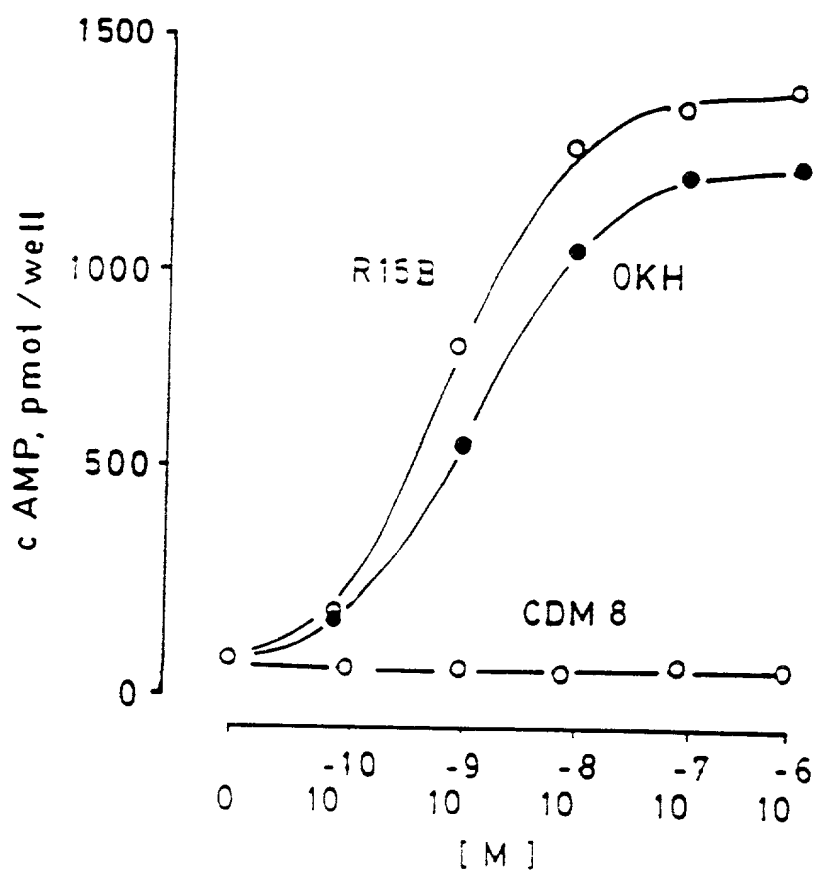
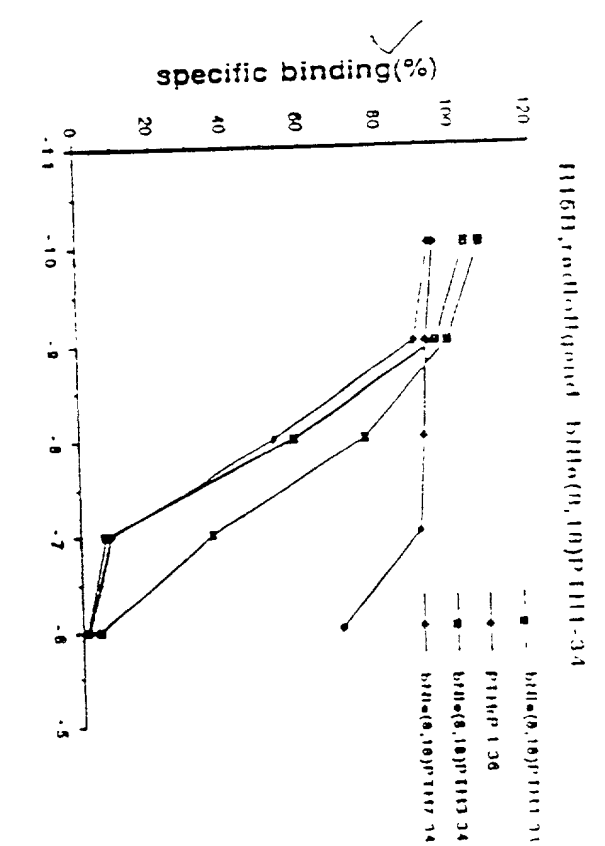
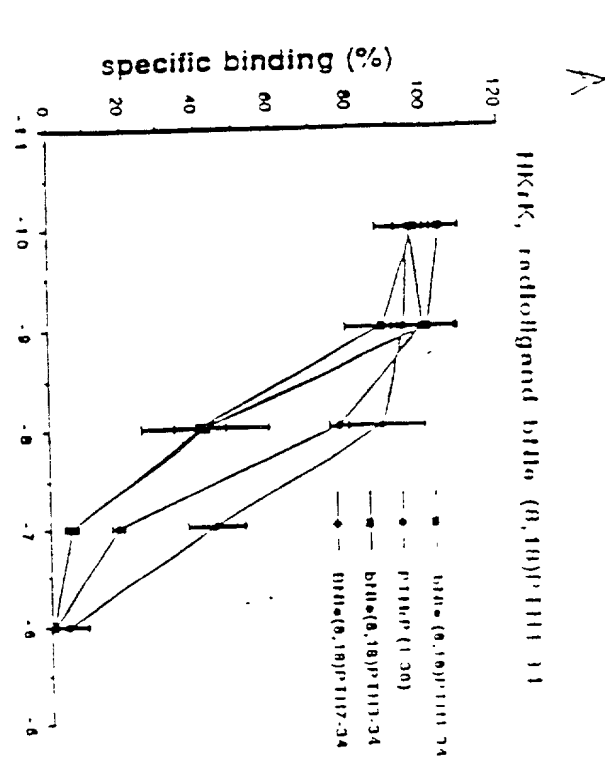
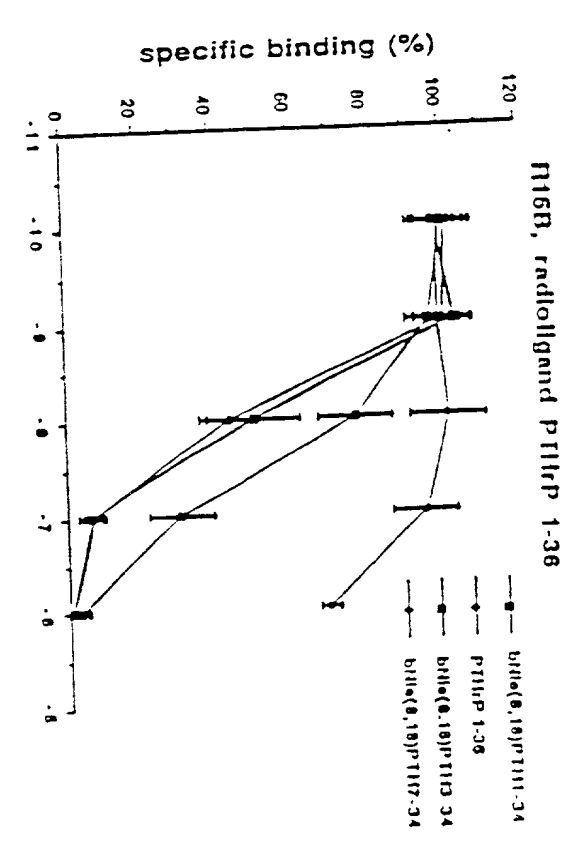
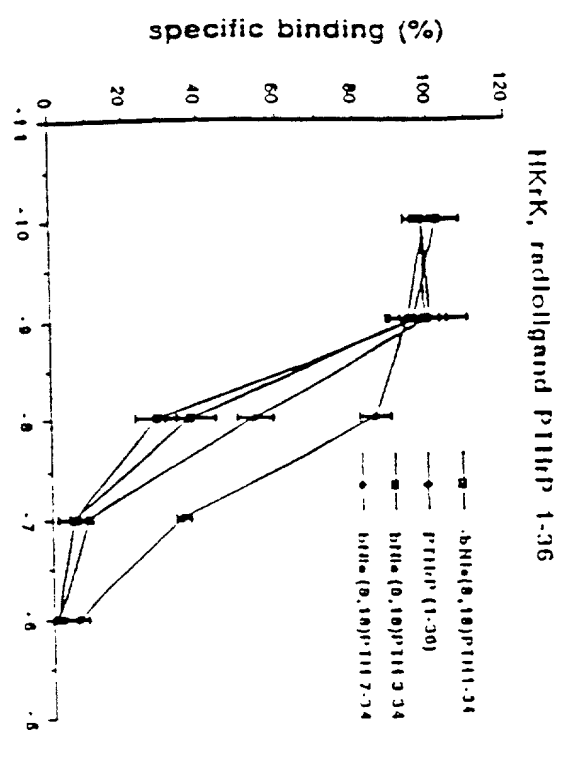
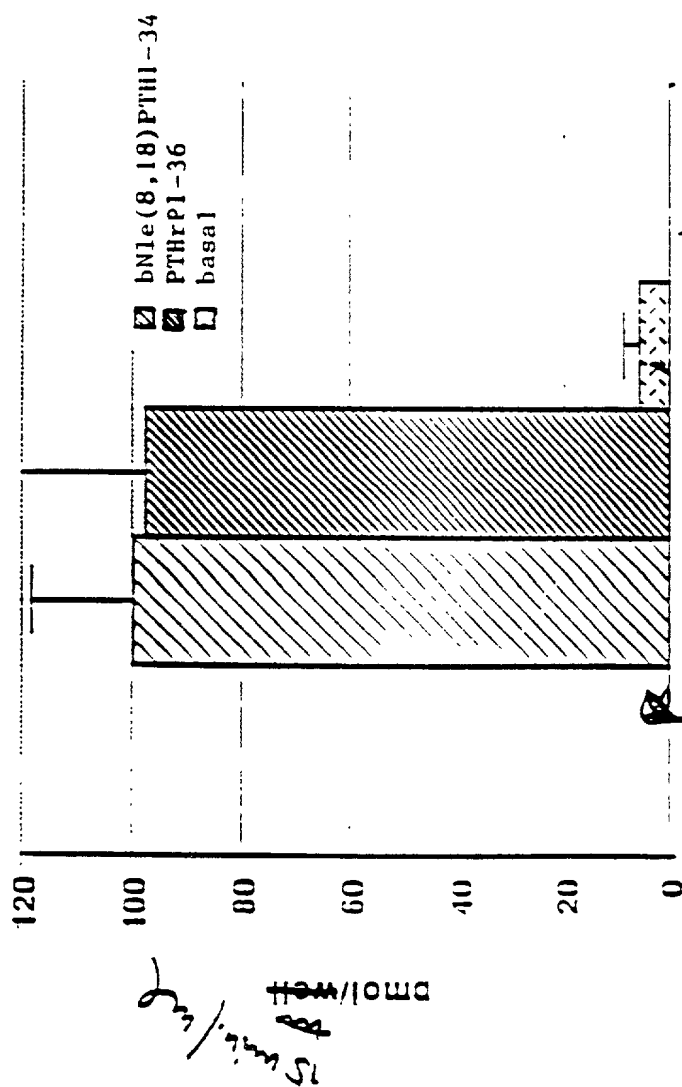


Fig. 17



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09499374 113403

Fig. 9



← 185

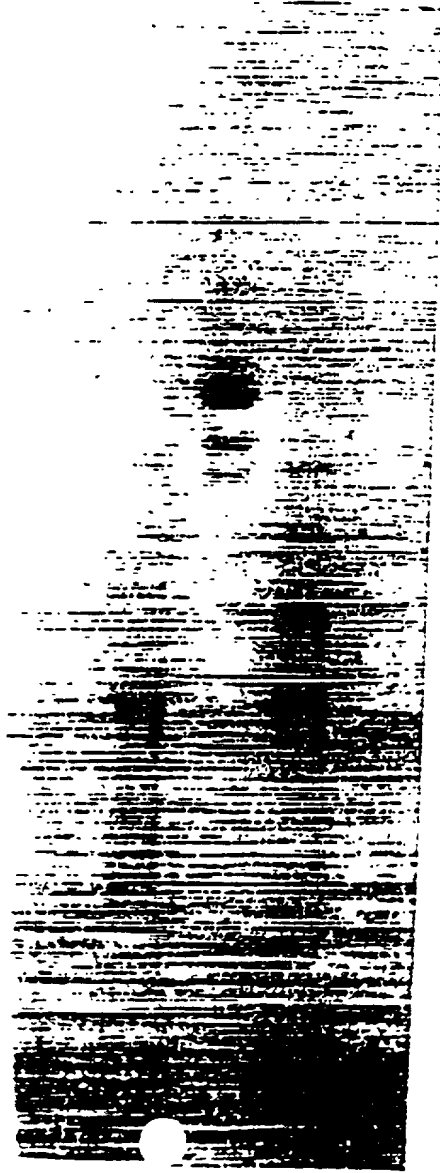
← 285

A B

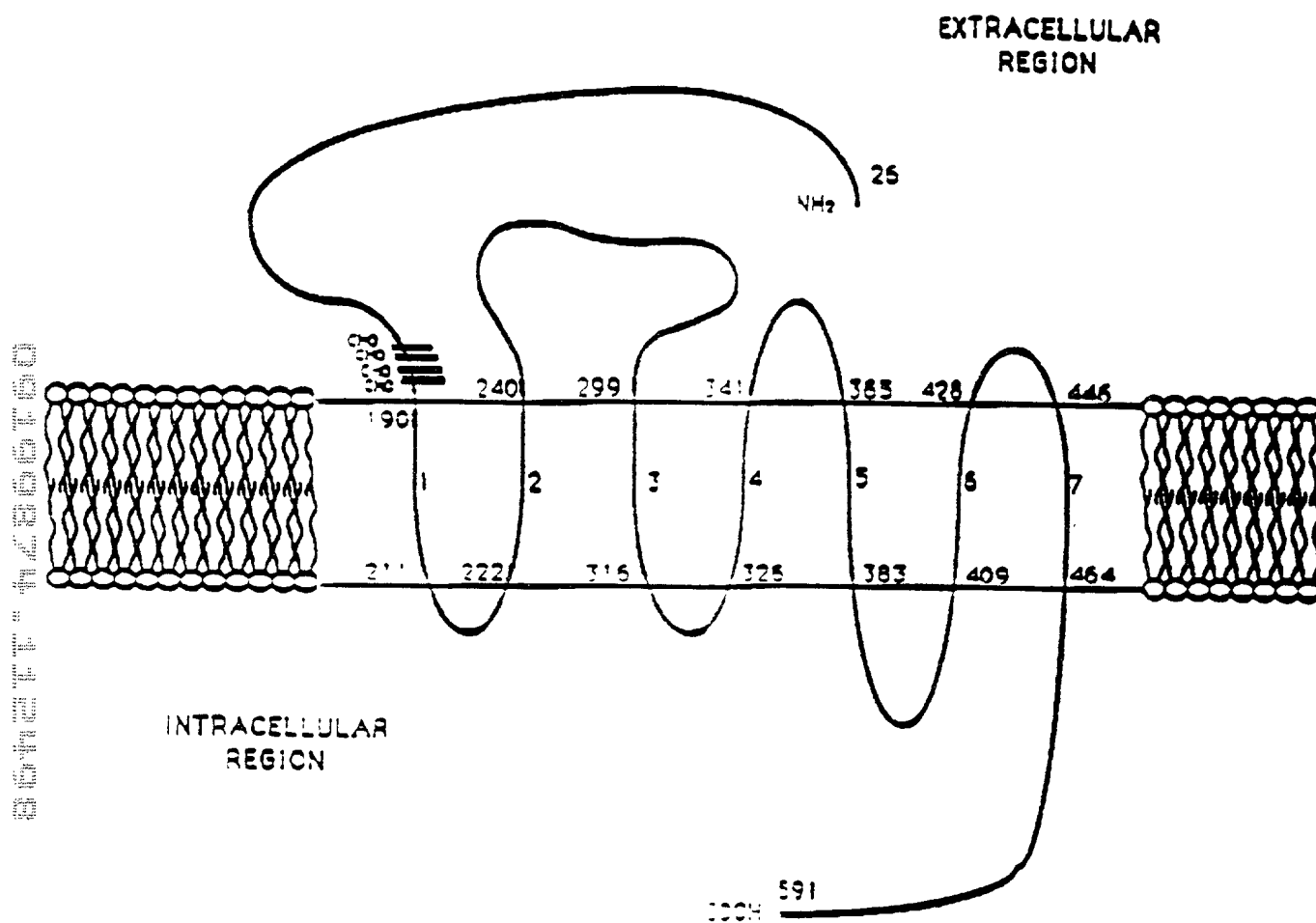


SECRET - REFLECTED

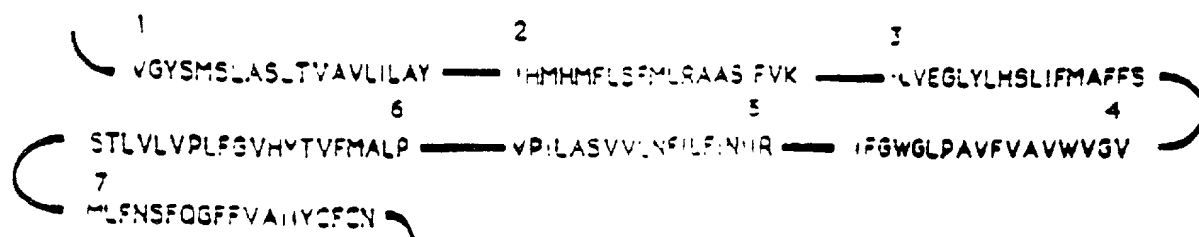
(S)



# RAT BONE PTH/PTHrP RECEPTOR



## AMINO ACID SEQUENCE OF 7 PUTATIVE TRANS-MEMBRANE REGIONS



[illegible]

I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled PARATHYROID HORMONE RECEPTOR AND DNA ENCODING SAME the specification of which

\_\_\_\_\_ was filed on \_\_\_\_\_  
as Application Serial No. \_\_\_\_\_ and was amended on \_\_\_\_\_

Prior Foreign Application(s):

Number	Country	Date Filed	Yes	No
Number	Country	Date Filed	Yes	No
Number	Country	Date Filed	Yes	No

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

<u>07/681,702</u>	<u>April 5, 1991</u>	
(Application Serial No.)	(Filing Date)	(Status)

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: Paul T. Clark, Reg. No. 30,162 and Janis K. Fraser, Reg. No. P34,819.

Address all telephone calls to Janis K. Fraser, Esq. at telephone no. (617) 542-5070.

Address all correspondence to Paul T. Clark, Esq. Fish & Richardson, 225 Franklin Street, Boston, MA 02110-2804.

[illegible]

Full Name of Inventor Gino V. Segre

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Full Name of Inventor Henry M. Kronenberg

Inventor's Signature \_\_\_\_\_ Date \_\_\_\_\_

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Full Name of Inventor Abdul-Badi Abou-Samra

Inventor's Signature \_\_\_\_\_ Date \_\_\_\_\_

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Full Name of Inventor Harald Juppner

Inventor's Signature \_\_\_\_\_ Date \_\_\_\_\_

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**COMBINED DECLARATION AND POWER OF ATTORNEY - CONTINUED**  
(Continuation or CIP Application)

Full Name of Inventor John T. Potts, Jr.

Inventor's Signature \_\_\_\_\_ Date \_\_\_\_\_

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Full Name of Inventor Ernestina Schipani

Inventor's Signature \_\_\_\_\_ Date \_\_\_\_\_

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—

SECRET - 42809750

**COMBINED DECLARATION AND POWER OF ATTORNEY**  
(Continuation or CIP Application)

As a below named inventor, I hereby declare that:  
My residence, post office address and citizenship are as stated below next to my name,  
I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled PARATHYROID HORMONE RECEPTOR AND DNA ENCODING SAME the specification of which

\_\_\_\_\_ is attached hereto.

X was filed on April 6, 1992  
as Application Serial No. 07/864,475 and was amended on \_\_\_\_\_.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s):

Number	Country	Date Filed	Yes	No
_____	_____	_____	_____	_____
Number	Country	Date Filed	Yes	No
_____	_____	_____	_____	_____
Number	Country	Date Filed	Yes	No
_____	_____	_____	_____	_____

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

<u>07/681,702</u>	<u>April 5, 1991</u>	<u>pending</u>
(Application Serial No.)	(Filing Date)	(Status)
_____	_____	_____
(Application Serial No.)	(Filing Date)	(Status)

COMBINED DECLARATION AND POWER OF ATTORNEY - CONTINUED  
(Continuation or CIP Application)

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: Paul T. Clark, Reg. No. 30,162 and Janis K. Fraser, Reg. No. 34,819.

Address all telephone calls to Janis K. Fraser, Esq. at telephone no. (617) 542-5070.

Address all correspondence to Paul T. Clark, Esq. Fish & Richardson, 225 Franklin Street, Boston, MA 02110-2804.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patents issued thereon.

Full Name of Inventor Gino V. Segre

Inventor's Signature *Gino V. Segre* Date 6/17/92

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Full Name of Inventor Abdul-Badi Abou-Samra

Inventor's Signature *Abou Samra* Date 6/8/92

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Citizenship *Syria*

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6/17/92 4:23:56 PM

Variable	Mean	SD	Min	Max
Age	35.2	12.5	18	65
Gender	Male	10.5	0	20
Marital Status	Married	15.2	0	20
Education	High School	5.5	0	12
Occupation	Unemployed	12.5	0	20
Income	\$15,000	\$10,000	\$0	\$40,000
Health Status	Good	10.5	0	20
Smoking Status	Non-smoker	12.5	0	20
Alcohol Consumption	Low	5.5	0	12
Exercise Frequency	Low	5.5	0	12
Stress Level	High	10.5	0	20
Sleep Quality	Good	10.5	0	20
Depression Score	Low	5.5	0	12
Anxiety Score	Low	5.5	0	12
Life Satisfaction	Low	5.5	0	12
Overall Health	Good	10.5	0	20

Inventor's Signature Harold J. Jumper Date 6-8-92

Citizenship U.S.A.

Full Name of Inventor John T. Potts, Jr.

Inventor's Signature [Signature] Date 6 8 92

Citizenship U.S.A.

Full Name of Inventor Ernestina Schipani

Inventor's Signature John H. [Signature] Date 6-8-1992

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